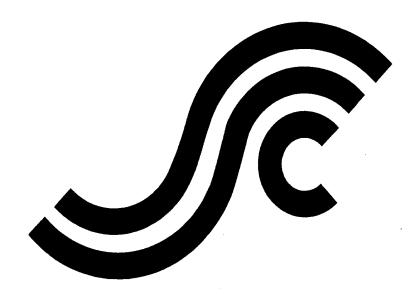
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SSC-408

DETECTION PROBABILITY ASSESSMENT OF VISUAL INSPECTION OF SHIPS



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An Interagency Advisory Committee

SR-1375 SSC-408

August 6, 1999

DETECTION PROBABILITY ASSESSMENT FOR VISUAL INSPECTION OF SHIPS

The work described in this report is part of an ongoing effort to determine the probability of detection (POD) in marine structural inspections. An understanding of POD can help ensure safe, cost-effective lifecycle operation of marine structures, allowing the appropriate combination of design assumptions and scheduled inspections. Work to date at U.C. Berkeley has focused on the inspection of oil tankers.

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R. C. NORTH

Rear Admiral, U. S. Coast Guard Chairman, Ship Structure Committee



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16. Abstract

The work described in this report is part of an ongoing effort to determine the probability of detection (POD) in marine structural inspections. An understanding of POD can help ensure safe, cost-effective lifecycle operation of marine structures, allowing the appropriate combination of design assumptions and scheduled inspections. Work to date at U.C. Berkeley has focused on the inspection of oil tankers.

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In the work described here, in situ experiments are used as a means of obtaining POD information. The rationale for the use of in situ experiments is first described, along with the advantages and disadvantages of these experiments with respect to other means of obtaining POD information. Results of this experiment are presented as well. Conclusions regarding POD in tanker inspection and regarding the in situ inspection method are drawn in the final section of this report.

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CONVERSION FACTORS

(Approximate conversions to metric measures)

To convert from	To	Function	Value
LENGTH			
inches	Meters	divide	39.3701
inches	Millimeters	multiply by	25.4000
feet	Meters	divide by	3.2808
VOLUME	1,10,015		2200
cubic feet	cubic meters	divide by	35.3149
cubic inches	cubic meters	divide by	61,024
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inches ² feet	centimeters ² meters	multiply by	1.9665
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FORCE OR MASS	centimeters	mumpiy by	41.023
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long tons	Kilograms	multiply by	1016.047
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pounds	Kilograms	divide by	2.2046
pounds	Newtons	multiply by	4.4482
PRESSURE OR STRESS	140 W tolks	manipiy oy	1.1102
pounds/inch ²	Newtons/meter ² (Pascals)	multiply by	6894.757
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BENDING OR TORQUE	(mega raseas)		
foot tons	meter tons	divide by	3.2291
foot pounds	kilogram meters	divide by	7.23285
foot pounds	Newton meters	multiply by	1.35582
ENERGY			
foot pounds	Joules	multiply by	1.355826
STRESS INTENSITY			
kilo pound/inch² inch½(ksi√in)	mega Newton MNm ^{3/2}	multiply by	1.0998
J-INTEGRAL			-
kilo pound/inch	Joules/mm ²	multiply by	0.1753
kilo pound/inch	kilo Joules/m ²	multiply by	175.3
TEMPERATURE			
Degrees Fahrenheit	Degrees Celsius	subtract	32
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1. Introduction

The work described in this report is part of an ongoing effort to determine the probability of detection (POD) in marine structural inspections. An understanding of POD can help ensure safe, cost-effective lifecycle operation of marine structures, allowing the appropriate combination of design assumptions and scheduled inspections. Work to date at U.C. Berkeley has focused on the inspection of oil tankers.

In a previous project, a preliminary model of the factors affecting POD in tanker inspection was developed, and is shown in Figure 1. Reviews of literature and interviews with inspectors indicated that the factors associated with an inspector, in particular, experience, would likely be important determinants of POD, along with factors such as access and lighting. Several approaches for evaluating POD were identified, with benchmarked inspection data (a comparison of two inspections of the same structure that take place within a relatively short time) and in situ experiments (a comparison of the performance of multiple inspectors inspecting the same structure under controlled conditions) considered to be the most promising. An application of the benchmarked inspection data approach to historical survey data for two ships highlighted the importance of several factors: prior knowledge of the history of a particular vessel and sister ships, the purpose of the inspection, and factors such as lighting, access, and cleanliness that may be different for different tanks on the same ship. The POD factor model and selected data from the benchmarked inspection case study can be found in [Demsetz et al. 1996b]. The full literature review, model development, and case study results can be found in [Demsetz et al. 1996a]

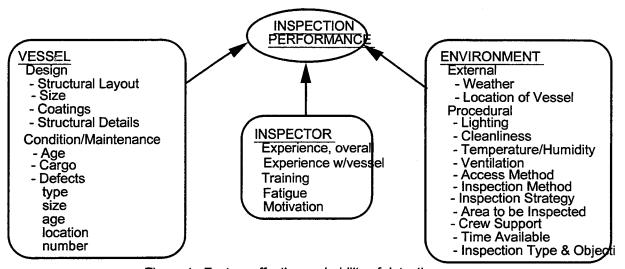


Figure 1. Factors affecting probability of detection.

In the work described here, in situ experiments are used as a means of obtaining POD information. The rationale for the use of in situ experiments is first described, along with the advantages and disadvantages of these experiments with respect to other means of obtaining POD information. Results of an initial in situ experiment, conducted in Portland, Oregon, in September, 1995, are then presented. Based on these results, the experimental protocol was revised. Using the revised protocol, a second experiment was conducted in Port Arthur, Texas, in July, 1996. Results of this experiment are presented as well. Conclusions regarding POD in tanker inspection and regarding the in situ inspection method are drawn in the final section of this report. The data from the two experiments are summarized in Appendices B and C.

1.1 In Situ Experiments

Previous studies have suggested several means of acquiring POD information, including solicitation of expert opinion, laboratory experiments, benchmarked historical data, and in situ experiments [Ayyub and White 1992, Demsetz et al. 1996a]. These methods and their relative advantages and disadvantages are summarized in Table 1. In manufacturing industries, POD curves are generated using test samples and recording the results of inspections under controlled conditions [Rummel 1989]. In dealing with larger structures, the aviation industry has used controlled experiments on specimens representing a portion of the structure [Berens 1989] and a comparison of the results of inspections of differing levels of rigor (similar to the benchmarked historical data approach) [Dinkeloo 1978]. Recent work on POD in offshore structures has involved controlled laboratory experiments on full scale samples that represent a portion of an offshore structure [Rudlin 1992].

Approach	Advantages	Disadvantages
Solicitation of Experts: ask experts to estimate POD for a variety of circumstances.	low cost; few time constraints; few resources required; easy data management	some experts are unable or unwilling to provide an estimate of POD; experts in tank inspection may not accurately estimate POD
Laboratory Experiments: carry out inspections in a controlled environment on test specimens constructed to contain the range of defects of interest.	ability to control test conditions; knowledge of true condition; fewer time constraints than in situ experiments	difficulty in recreating field environment; costly if large specimens used
Benchmarked Inspection Data: comparison of results of subsequent inspections, specifically an underway inspection with a drydock inspection shortly thereafter	low cost; few resource requirements;	little or no control over factor conditions; no guarantee that drydock inspection yields "true" condition of tank; few examples of usable historical data
In-Situ Experiments: experiments carried out on an in-service or temporarily out- of-service vessel	ability to replicate field environment;	high cost, especially of keeping vessel out of service; chance that too few defects exist to provide meaningful results (unless markers used as to "simulate" defects)

Table 1. Methods of Determining Probability of Detection.

The in situ tank inspection experiments described in this report were carried out in "real" structures: tankers that, while temporarily out of service, provide an experimental environment that comes as close as possible to duplicating the actual field condition of an underway inspection. The major advantage of an in situ experiment is this close replication of actual field conditions. Although each inspectors' motivation during the experiment may differ from that in his or her normal job practice, other inspector factors and the vessel and environmental factors are true to life. Thus, in situ experiments provide an opportunity to assess overall POD and to investigate the impact of inspector factors on POD. In the experiments described here, inspectors carried out an equivalent of an underway (or voyage) inspection, rather than the more thorough inspection done during a periodic overhaul in a shipyard (where a better environment, one more "friendly" to inspection, is available).

There are, however, disadvantages to in situ experiments. The resource requirements are significant; a vessel and a group of inspectors must be brought to the same place at the same time. Associated costs include the cost of the inspectors and, most significantly, the cost of keeping the vessel out of service for several days. In the experiments described in this report, the vessels were temporarily out of service for other reasons. This made the experiments economically feasible. A major disadvantage of in situ experiments is that the condition of the vessel is unknown before the experiment starts. It may turn out that the vessel has few defects of interest, and that the experiment, while executed correctly, yields no useful data regarding probability of detection. To guarantee that at least some data were obtained from the experiments described here, markers that were roughly as difficult to detect as real defects were placed in portions of the vessels.

1.2 Pre-experiment Planning

At the time this research project was awarded, it was anticipated that one experiment would be carried out during the first year of the project, on a vessel to be determined, and that a second experiment would be carried out during a possible second year of the project. Shortly after the project started, a vessel that was to be laid up at dockside for an unknown length of time was identified. The owner of the ship agreed to let it be used as the site for the experiment. Because there was a significant chance that the ship would be placed back in active service shortly, the experiment was planned and carried out as quickly as possible. Planning issues regarding the ship, the inspectors, and the preparation of the tanks prior to the experiment are described in this section.

1.2.1 General Plan

The general plan for the experiment called for three types of inspection. The first, a standard visual inspection, was carried out independently by each of several inspectors. After the inspection, each inspector was asked to complete a brief questionnaire (developed in [Demsetz 1996a]) designed to capture the levels of the various factors shown in Figure 1. The results of these standard visual inspections were aggregated and analyzed; the results were provided to the team carrying out the second type of inspection: the visual follow-up. In order to allow each team to inspect the tank under the same conditions, the inspectors were instructed not to scrape, mark, or otherwise disturb the tank. Thus, in areas where waxy build-up or corrosion were present, the inspectors were reporting "suspect areas" — areas they would have scraped if possible — rather than actual cracks. Because the tank's condition remains constant throughout the experiment, the vessel and environment factors (except for time in tank) remain the same for each inspector.

The purpose of the second inspection, the visual follow-up, was to determine the "true" state of the vessel. The follow-up inspector was asked to verify the standard visual inspections and to

take as much time and as much care as possible to identify any additional cracks. The aggregated results of the standard inspections, augmented with the findings of the visual follow-up, would be considered the "true" data as far as existence and location of cracks.

The third type of inspection, non-destructive evaluation, was to be carried out to assess the true length of cracks as part of a related project. The lengths observed through non-destructive evaluation techniques were to be compared with the lengths recorded during visual inspections of the same cracks. Non-destructive evaluation was carried out on only two cracks during the first experiment. Non-destructive evaluation was not included in the second experiment.

1.2.2 Markers

There was concern in advance of the experiment that the effort would be wasted if the tanks that were inspected turned out to contain few cracks. Therefore, to make sure that at least some usable information would be obtained, it was decided that an additional tank would be outfitted with markers. A marker would be roughly as difficult to see as a crack, but would not necessarily look like a crack. The markers would be placed in locations where cracking could reasonably be anticipated, and in some additional locations as well.

During the first experiment, the follow-up inspector did not clean the suspect areas because it was anticipated that the tank would be used in a subsequent experiment. During the second experiment, the follow-up inspector cleaned all suspect areas.

2. Experiment One

2.1 The Ship

Experiment One was carried out on Ship One, a 165,000 DWT oil tanker. At the time of the experiment, Ship One was laid up at dockside in Portland, Oregon. The cargo tanks had been cleaned after the last voyage.

The general arrangement of the tanks and a typical midsection are shown in Figure 2. For the experiment, Cargo Tanks 3P, 3S, and 5P were used. Based on an earlier walk-through of the tanks, the owner anticipated that there would be between 10 and 20 fractures in each of Tanks 3P and 3S. The owner also provided historical information on locations of cracks in Ship 1 and sister ships. This information was used to guide the placement of markers in Tank 5P.

2.2 The Inspectors

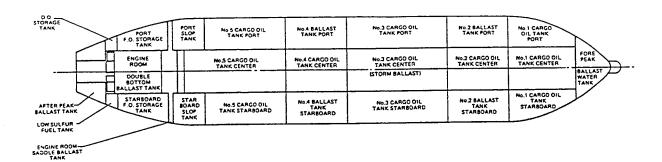
Once Ship 1 was identified as the platform for the experiment, and Portland, Oregon, as the location, the United State Coast Guard (USCG) recruited inspectors to participate in the study. The goal was to allow as many inspectors as possible to participate while limiting the length of the experiment to two or three days. Six inspectors — four from the USCG, one from the American Bureau of Shipping (ABS), one from a commercial firm — completed the entire experiment; a seventh (from ABS) inspected only Tanks 3P and 3S. The inspectors varied greatly in their experience; two of the USCG inspectors did not carry out inspections as part of their jobs at the time of the experiment. More information on the inspectors is included in Section 2.5.1.

2.3 The Schedule

Experiment 1 was carried out September 25-28, 1995. On the afternoon of September 25, an owner's representative, UC researchers (Cabrera and Demsetz), and a U.S. Coast Guard representative walked through Tanks 3P, 3S, and 5P to assess overall condition and to label frames and selected longitudinals (see Section 2.4). Markers were placed on September 26. Visual inspections were carried out on September 27; results from all participants were aggregated that evening to develop a baseline for the follow-up inspection, which took place on the morning of September 28.

2.4 Tank Preparation

The first step in preparing the tanks for the experiment was to become familiar with the tank structure and the areas that were historically prone to fracture. In addition, the preliminary locations for markers that had been developed before visiting the ship had to be verified as reasonable given the observed structure and condition of Tank 5P. Tank preparation involved a walk-through of the tanks, labeling of the structure, and selection and placement of markers. Tank preparation was carried out by U.C. researchers and a member of the USCG, with assistance from a representative of the ship's owner. Prior to the experiment, the tanks had been ventilated. The tanks were gas free at the time of the experiment. Blowers were used as necessary through the experiment so that participants were able to carry out inspections without wearing half-mask respirators.



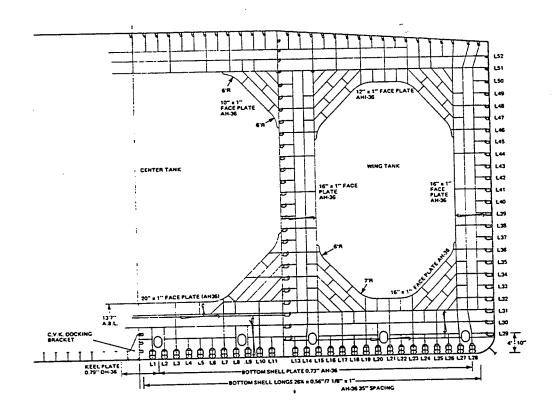


Figure 2. General Arrangement and Typical Midsection, Ship One.

2.4.1 Walk Through

A representative of the ship's owner gave a thorough walk through of Tanks 3P, 3S, and 5P. Locations that had a previous history of fatigue or fracture problems on this or sister ships were pointed out. All three tanks were found to be in relatively dry condition and free of debris.

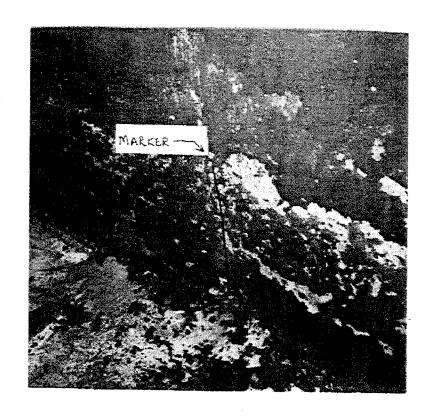
2.4.2 Labeling

During the walk through, web frame and selected longitudinals were labeled to correspond to the owner's numbering system. This was done for two reasons: first, so that inspectors not familiar with the ship would more easily be able to orient themselves; and second, to reduce errors in recording the location of cracks and markers.

2.4.3 Marker Selection and Placement

In Tank 5P, markers were used to simulate cracks. The intent was that the markers be roughly as easy or hard to detect as cracks, not that they necessarily look like cracks. An additional objective was that a marker, once detected, could be easily identifiable by an inspector as indeed being a marker. Lead pencils, grease pencils of various colors, and brown and black architectural drafting tape in 1/8 and 1/16-inch widths were tried on various locations within Tank 5P. A lead pencil line most closely resembled a crack. However, in locations with waxy buildup, it was difficult to mark with the pencil without significantly disturbing the surface. Furthermore, in some locations it was difficult to determine whether the pencil mark was indeed a pencil mark or was just a shadow. Of the other marker options, the black architect's tape most closely satisfied the detectability criterion; in many different locations, it was roughly as easy to detect as a crack. Once seen, the black tape was clearly identifiable as a marker; inspectors would not confuse it with any other feature in the tank. Although the black tape did not stick well in a few locations where there was dusty or dried residue, in most locations it adhered well to the tank structure and any residue present. Therefore, black architect's tape was selected as the marker material. Figure 3 shows typical markers.

Preliminary marker locations had been derived from information provided by the ship owner prior to the experiment. At the time of the experiment, these locations had to be verified as realistic fatigue areas and as being suitable for marker placement (that is, free of dusty or dried residue). The first criterion was not completely satisfied. Of the three tanks available, Tank 5 was considered least likely to contain actual cracks. It was therefore selected for use in the marker portion of the experiment. However, because cracking would not be anticipated in Tank 5, there were no truly "realistic" areas in which to place the markers. Markers were placed in locations similar to those historically prone to fracture in tanks located in the forward portion of the ship. In addition, a few markers were placed in locations where fractures would not be expected in the forward tanks. There are referred to as "rogue" markers. All told, 106 markers were placed; of these, 98 remained in place throughout the experiment. These included 81 markers in locations historically prone to fracture in the forward tanks and 17 rogue markers.



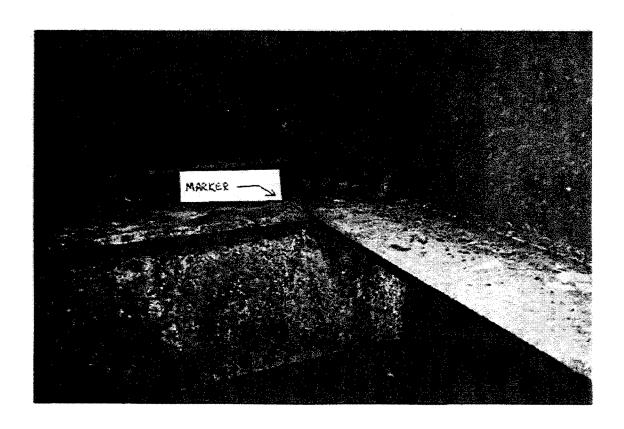


Figure 3. Typical Markers, Ship One.

2.5 The Experiment

U.C. Berkeley researchers (Cabrera and Demsetz) and a U.S. Coast Guard representative served as coordinators for first experiment. The weather during the experiment was pleasantly cool, with occasional light rain.

2.5.1 Participants

Six inspectors took part in the complete experiment; a seventh inspected only Tanks 3P and 3S, and is not included here. The inspectors had different levels of experience in tank inspection and were from different organizations. In a previous research project, a questionnaire was developed to record conditions for many of the Inspector and Environment factors shown in Figure 1 [Demsetz et al. 1996]. The questionnaire and responses from each inspector are included in Appendix A. Table 2 summarizes the participating inspectors' experience, as reported on the questionnaire.

		Inspector and affiliation				
	1 USCG	2 USCG	3 USCG	4 USCG	5 CLASS	6 COMM
Hours of inspection in 7 days prior to experiment	<50	50-64	<50	<50	50-64	50-64
Years of inspection experience	5-8	2-4	0-2	5-8	>9	5-8
Prior inspections of Ship 1	0	0	0	0	>3	>3
Prior inspections of sister ship(s)	>5	1-2	0	0	>5	>5
Prior inspection training (years)	1-2	1-2	<0.5	0.5-1	>2	0.5-1
Viewed ship's past inspection reports prior to experiment?	No	Yes	No	No	No	No

USCG = U. S. Coast Guard; CLASS = Classification Society; COMM = Commercial Inspector.

Table 2. Inspectors' Experience, Experiment One.

Various levels of general inspection experience are represented among the inspectors. Although only two of the inspectors had previously inspected Ship 1, two other inspectors had carried out inspections of at least one of the vessel's sister ships. Only one of the six inspectors had reviewed prior inspection reports for the Ship 1.

2.5.2 Tank Inspection

For the initial visual inspections, the inspectors were divided into groups of two. Each group started in a different tank. To minimize interaction between inspectors, inspectors in the same tank started their inspections on opposite ends of the tank. One of the coordinators was present in each tank at all times to observe the participants and as a safety measure. Additional safety precautions included direct radio communication between all the coordinators and the ship's crew. The communication channel was frequently checked to ensure proper radio operation and to maintain contact between all parties.

Inspectors were initially allotted two hours in each tank. However, the large number of markers used in Tank 5P greatly increased the time required in this tank. The coordinator in Tank 5P estimated that it took approximately one minute for an inspector to record a marker or crack. An inspector who found only half of the 98 markers in Tank 5P would still required nearly an hour just to record this information. To allow each participant to finish the inspections for all three tanks, inspectors who started in Tanks 3P and 3S were allowed to enter Tank 5P immediately after completing the initial tank. This meant that at times there were as many as four inspectors in Tank 5P, but the tank was large enough that interaction between inspectors was still minimal.

Inspectors were asked not to scrape, wipe, or otherwise disturb the tank. In most locations in the tanks, waxy build-up and corrosion made it impossible to determine, without disturbing the tank, whether a crack existed. In Tanks 3P and 3S, inspectors were instructed to record both fractures and "suspect areas"; areas that they would have scraped in an actual inspection. In Tank 5P, inspectors were asked to look for actual cracks and markers. However, with few cracks and many markers, the inspectors ultimately focused on markers only.

Climbing along the shell or inboard bulkheads was not permitted, and access was limited to below the third longitudinal as measured from the bottom. The inspectors were asked to use whatever means of recording the information they were comfortable with; most used a pencil and notepad to record their results.

Upon the completion of each tank inspection and prior to continuing to another tank, each inspector was debriefed by a coordinator who recorded location, fracture type and length, and any other pertinent information for each fracture found. When an inspector was done with all three tanks, the questionnaire in Appendix A was completed. Questionnaire responses were used to determine the impact of various factors on detection rate.

2.5.3 Follow-up Inspection

In the evening following the initial inspections, the coordinators combined the results from the individual inspectors to form a master list. To reduce the chances of misinterpreting the inspection reports, the location and description of each fracture and suspect area were included in the same words as reported by the inspectors during the experiment.

On the next day, a follow-up inspection was carried out to verify the reported fractures. One of the participants, a commercial inspector who had prior experience with the test ship, conducted the follow-up visual inspection to verify the fractures as reported in the baseline data set for Tanks 3P and 3S. Because it was anticipated that this ship might be used for the second experiment as well, the follow-up inspector was also instructed not the mark or scrape the tank except for the few instances when NDT techniques were applied. No time limit was set for the follow-up inspection.

Following the experiment, the coordinators went through Tank 5P and verified that the markers were still attached at the locations where they were placed prior to the experiment. Of the 106 samples that were put in place two days earlier, eight could not be found. Thus the baseline for Tank 5P consists of 98 markers.

2.6 Results

Results from the inspections of Ship 1 are included in Appendix B. A qualitative assessment of the experiment is provided here, followed by a quantitative analysis of detection rate and the factors that affect it.

2.6.1 Qualitative Analysis

The instructions for the experiment requested inspectors to record the length and location of suspected fractures or areas of buckling. Most of the reported defects in tanks 3P and 3S were areas of corrosion or washed out welds; however, due to the nature of the instructions, these areas are not included in the analysis. In all, 14 fractures or suspect areas were found in Tank 3P, while 22 fractures or suspect areas were found in 3S. Waxy build-up was present throughout the tanks. Inspectors were prohibited from scraping away the residue during the experiment, and were therefore limited, in many cases, to reporting suspect areas — areas that they would have scraped if permitted to. This was a problem in both the initial visual inspections and in the follow-up inspections as well, and was especially common along the bottom shell. The reporting of suspect areas rather than actual cracks makes it difficult to analyze the results. A more skilled inspector might be better both at finding questionable areas and at discerning that they do not, in fact, indicate a fracture. An inspector who identifies fewer areas as suspect may in fact have a greater detection rate than one who identifies more suspect areas if the additional areas do not turn out to be fractures.

During the follow-up inspection, the inspector was asked to scrape several suspect locations and measure fracture length using a non-destructive technique (magnetic particle) so that visual estimates of crack length could be compared with nondestructive testing results. The inspector was not under a time constraint during the follow-up procedure, but the wax deposits made the verification process quite tedious. In the end, conclusions based on the comparisons between visual and nondestructive techniques could not be made.

In Tank 5P, some inspectors appeared to conduct their examination of the tank's structure with a different strategy than in Tanks 3P and 3S. Rather than focus on locations where fracture would have been expected in another tank, they searched throughout the entire (accessible) structure for markers. The physical appearance of the black architectural tape against the dark wax deposits made detection of the markers difficult in some locations. In some cases, the inspectors seemed to search for the slight reflections of a flashlight beam as it came across a piece a black tape.

2.6.2 Quantitative Analysis

Table 3 shows the overall results for each inspector in each tank. The term "hit rate" is used (rather than "probability of detection") to emphasize the inaccuracy inherent in the reporting of suspect areas. For these tanks, the calculated rate is based on the total number of verified fractures and suspect areas. That is, only identifiable fractures and areas considered to be suspect by the follow-up inspector are included. As noted above, the follow-up inspector was not permitted to scrape most of the suspect areas. Therefore, the denominator used to calculate the hit rate for Tanks 3P and 3S does not necessarily represent the true condition of the tank. In Tank 3S, each of the 22 reported fractures/suspect areas was found by only a single inspector. Due to the small number of data points, the disparity in suspect locations reported by the different inspectors, and the difficulty in defining a suspect area, no further analysis of Tanks 3P and 3S was carried out.

Tank:	5P	3P	3S
Defect type:	marker	suspect area or	suspect area or
		fracture	fracture
Number of defects:	98	14	22
Inspector (affiliation)	Detection Rate	Hit I	Rate
1 (USCG)	.53	.21	.05
2 (USCG)	.65	.43	.33
3 (USCG)	.40	.07	.00
4 (USCG)	.32	.07	.05
5 (CLASS)	.27	.21	.50
6 (COMM)	.49	.21	.09
Average	.44	.20	.17

USCG = U. S. Coast Guard; CLASS = Classification Society; COMM = Commercial Inspector.

Table 3. Results by Inspector, Experiment One

The remainder of the analysis of data from Experiment One focuses on the detection of markers in Tank 5P, and on determining the factors that affect detection rate.

One factor that may affect inspection rate is the amount of time available for an inspection (procedural environment factor in Figure 1). Inspectors 2 and 6 measured each marker that they found. It is estimated that this added roughly 10 seconds to the time required to record each marker that these inspectors detected, as compared with the time required by other inspectors. Thus, in evaluating the effect of time in tank, an "adjusted time in tank" is used for inspectors 2 and 6. The adjusted time is the observed time less 10 seconds for each marker found.

Inspector 3, who had no previous tank inspection experience, was observed to carry out a very careful examination of all structural details. This resulted in a 0.40 overall detection rate, even though Inspector 3 did not have time to inspect the entire tank. In the portion of the tank inspected, Inspector 3's detection rate was 0.58. This modified detection rate is used in subsequent analysis.

It is important to keep in mind that, due to the possible differences in inspection strategy and ease of detection, the detection rate for markers may not be indicative of the detection rate for fractures. For Tank 5P, the detection rate shown in Table 3 is the percentage of the 98 markers that were found by a particular inspector. This rate ranges from 0.27 for Inspector 5 to 0.65 for Inspector 2.

2.6.2.1 Vessel Factors

Of the vessel factors shown in Figure 1, only the defect factors vary in this experiment. Defect size, location, and number can be compared with detection rate. Table 4 and Figure 4 shows the detection rate as a function of marker length. The number of markers at each length is also shown. Where there are 17 or more markers at a particular length, the mean detection rate ranges from 0.44 to 0.53.

		Detection Rate									
Length	number of		Inspector and affiliation								
mm	markers	1	2	3	4	5	6	MEAN			
:		USCG	USCG	USCG	USCG	CLASS	COMM				
12.5	1	1.00	0.00	0.00	0.00	0.00	0.00	0.17			
25	5	0.40	0.40	0.60	0.40	0.60	0.20	0.43			
50	31	0.52	0.65	0.45	0.35	0.23	0.42	0.44			
60	1	0.00	0.00	0.00	1.00	0.00	1.00	0.33			
75	37	0.54	0.70	0.38	0.30	0.30	0.49	0.45			
100	17	0.65	0.82	0.47	0.35	0.29	0.59	0.53			
150	4	0.25	0.00	0.00	0.00	0.00	0.75	0.17			
200	2	0.50	1.00	0.00	0.00	0.00	1.00	0.42			

USCG = U. S. Coast Guard; CLASS = Classification Society; COMM = Commercial Inspector.

Table 4. Detection Rate and Marker Length, Experiment One.

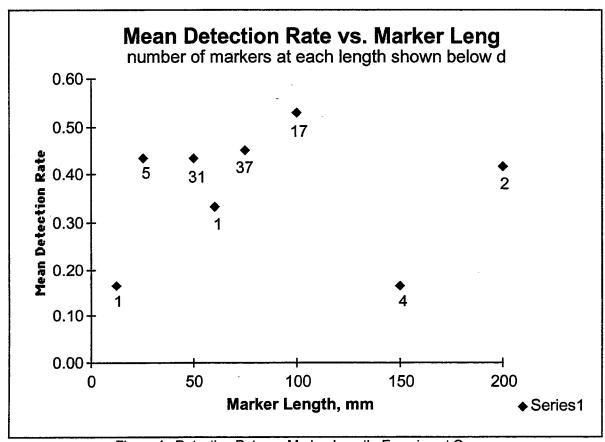


Figure 4. Detection Rate vs. Marker Length, Experiment One

Marker placement was such that the markers could be considered to represent defects in six generic locations, as shown in Table 5. Detection rates for "Butt Weld Seams" and "Stringer Plating" markers were noticeably lower than for other generic types. However, this may be due in part to the smaller number of markers in these categories.

Defect Type	Description	# markers	Detection Rate
1	Longitudinal to Web Connection	44	0.43
	Web to Bottom Connection	19	0.45
3	Bilge Brackets	9	0.56
4	Butt Weld Seams	5	0.23
5	Stringer Plating	3	0.28
6	Stringer Longitudinal Conn.	18	0.50

Table 5. Detection Rate and Marker Type, Experiment One.

2.6.2.2 Inspector Factors

The inspector factors shown in Figure 1 include factors related to experience (overall experience, experience with the particular vessel, training) and factors related to the inspector's current situation (fatigue and motivation). Questionnaire responses allow an investigation of the effect of the experience factors, and, to a lesser extent, the effect of fatigue. The only information regarding the motivation of the inspectors is through the researchers' casual observations.

Table 6 presents the available measures of experience along with the detection rate for each inspector. None of the factors shown in Table 4 correlates well with modified detection rate, although review of past inspection reports may have contributed to inspector 2's high detection rate.

	Inspector and affiliation								
	1 2 3 4 5								
	USCG	USCG	USCG	USCG	CLASS	COMM			
Inspection hours in previous week	<50	50-64	<50	<50	50-64	50-64			
Years of inspection experience	5-8	2-4	0-2	5-8	>9	5-8			
Prior inspections of Ship 1	0	0	0	0	>3	>3			
Sister ship(s) inspections	>5	1-2	0	0	>5	>5			
Inspection training (years)	1-2	1-2	<0.5	0.5-1	>2	0.5-1			
Past inspection reports reviewed?	No	Yes	No	No	No	No			
Detection rate, 5P	0.53	0.65	0.40	0.32	0.27	0.44			
Modified detection rate, 5P	0.53	0.65	0.58	0.32	0.27	0.44			

USCG = U. S. Coast Guard; CLASS = Classification Society; COMM = Commercial Inspector.

Table 6. Inspector Experience and Detection Rate, Experiment One

The effects of fatigue were investigated by looking at changes in detection rate as an inspector moved through Tank 5P; no evidence of a change in detection rate was found.

Only casual observations of inspectors' motivation can be made. Inspector 4, from the U.S. Coast Guard, had been closely involved in the development of this research project, and appeared to be highly motivated to do a thorough job of inspection. Inspector 3, from the U.S. Coast Guard, also appeared to be highly motivated to do a thorough job of inspection. Neither of the U.S. Coast Guard participants carried out inspection work as a part of their daily routine at the time that the experiment was conducted.

2.6.2.3 Environment Factors

Of the environment factors shown in Figure 1, only inspection strategy and time available varied among inspectors in this experiment. There is no objective information available on inspection strategy. However, Inspector 3, who had no prior tank inspection experience, was observed to work very carefully and methodically through Tank 5P, while the other inspectors initially carried out a broader scan of a particular area, then focused on critical areas. This "scan/focus" strategy appeared to change for at least some inspectors as they made their way through the tank and found markers in non-critical areas. Inspector 6 reported switching to an "Easter egg hunt" strategy; looking at all areas, rather than carrying out a broad scan and then focusing on critical areas.

Table 7 shows the time each inspector took in Tank 5P along with detect rate. Figure 5 shows this same information graphically. The two inspectors who spent the least time in Tank 5P also had the lowest detection rates. However, there is no clear relationship between time in tank and detection rate for the other inspectors.

	Inspector and affiliation							
	1	1 2 3 4 5						
	USCG	USCG	USCG	USCG	CLASS	COMM		
Adjusted time in tank, minutes	150	129	150	120	85	157		
Modified detection rate, 5P	0.53	0.65	0.58	0.32	0.27	0.44		

USCG = U. S. Coast Guard; CLASS = Classification Society; COMM = Commercial Inspector.

Table 7. Time in Tank, Experiment One.

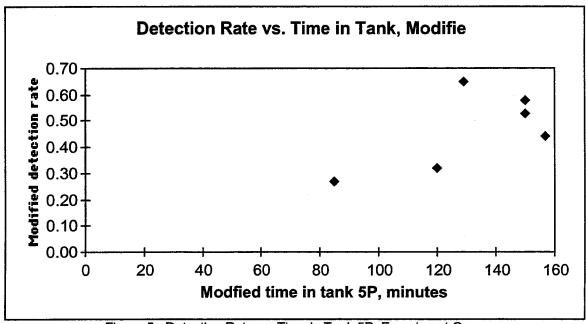


Figure 5. Detection Rate vs. Time in Tank 5P, Experiment One.

2.6.2.4 Factor Combinations

A variety of combinations of factors were investigated to attempt to explain detection rate. The detection rate is most accurately predicted by considering the adjusted time in tank along with whether or not past inspection reports were reviewed prior to the experiment. The only inspector to review past reports was Inspector 2; including this information allows Inspector 2's strong detection rate to be explained. However, the differences in inspection strategy between the marker inspection in Tank 5P and a normal inspection were such that these results should not be generalized to other situations.

2.7 Summary of Results of Experiment One

Several lessons were learned from Experiment One. First, it is always possible that an in situ experiment will indeed yield far fewer defects than anticipated. It therefore makes sense to continue the use of markers. However, the observed changes in inspection strategy in Tank 5P, which contained 98 markers, indicate that a more "realistic" number and placement of markers is required.

The experimental procedure used in Experiment One required inspectors to leave the tank undisturbed. Thus, inspectors could report only "suspect" areas, making it difficult to judge performance.

Finally, it is important to keep in mind that the detection rates observed in this experiment may be significantly different from actual practice due to changes in inspection strategy (among other issues), and should not be used other than to guide the direction of subsequent work.

3. Experiment Two

For Experiment Two, the protocol used in the first experiment was modified in two ways to address the problems observed. To provide at least some information on actual detection rates (as opposed to only the detection rates for suspect areas), the last inspector in a particular tank was allowed to disturb the tank's condition and scrape suspect areas to determine if they were indeed defects. Prior to the experiment, the owner of the ship felt certain that there would be many cracks in the tanks to be inspected. Markers were still used, both to help determine whether detection rates for properly placed markers were similar to detection rates for defects and in case there were fewer cracks than expected (which, in fact, there were). To permit inspectors to maintain their normal inspection strategy, far fewer markers were used and these markers were placed throughout the various tanks to be inspected (rather than concentrated in a single tank).

3.1 The Ship

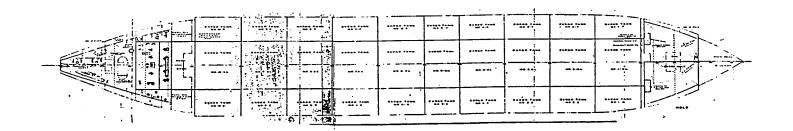
Experiment Two was carried out on Ship Two, a 32,650 ton deadweight oil tanker. At the time of the experiment, Ship Two was docked in Port Arthur, Texas. While other work was being done in anticipation of the replacement of the ship's forebody, the owner allowed access to the existing forebody for the inspection experiment. The existing forebody was to be scrapped, and the owner anticipated that it would contain many cracks. Figure 6 shows the general arrangement and typical midship section of Ship Two. In the side tanks, bottom longitudinal #20 (the center of the tank) had been built up; in the center tanks, bottom longitudinal #28 had been built up on each side of the center line.

3.2 The Inspectors

Seven inspectors participated in Experiment Two. Four were hired through a separate contract with a commercial inspector. Two inspectors were with the local USCG group. One inspector was provided by ABS. All participants regularly carried out inspections as part of their work at the time of the experiment. More information on the inspectors is included in Section 3.5.1.

3.3 The Schedule

Experiment 2 was carried out July 22-26, 1996. Prior to the dates of the experiment, U.C. Berkeley researchers (Cabrera and Demsetz) had only limited information on the ship. U.C. Berkeley researchers arrived in Houston on the afternoon of July 22, and reviewed inspection history of Ship Two at ABS Houston, and then drove to Port Arthur. On July 23, U.C. researchers walked through Ship Two's tanks, labeled tanks, and placed markers. Visual inspections were carried out on July 24 and the morning of July 25. Results of visual inspections were aggregated in the evening after the inspection so that a complete list was available for follow-up inspections. Follow-up inspections took place on the afternoon of July 25 and the morning of July 26. The weather was hot throughout the experiment, but especially on July 23 and 24.



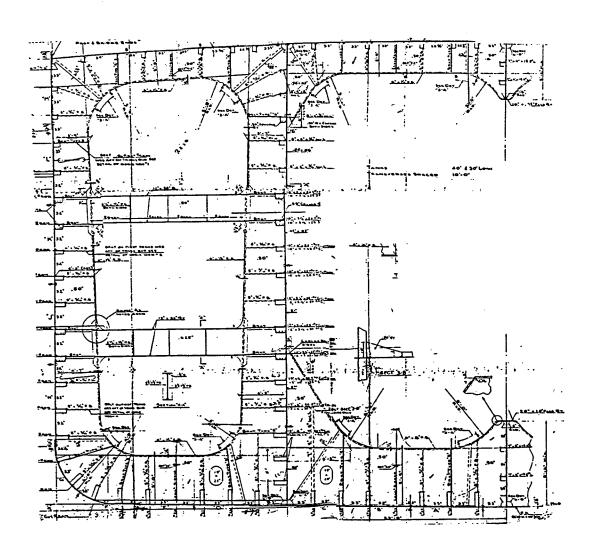


Figure 6. General Arrangement and Typical Midsection, Ship Two.

3.4 Tank Preparation

Eleven cargo tanks were used in this experiment, as shown in Figure 7. Tank 5S could not be used due to petroleum product at the base of the ladder. Tank preparation involved a walk-through of the tanks by U.C. Berkeley researchers, labeling of the structure in some tanks, and selection and placement of markers. Web frames and selected longitudinals were labeled (with white spray paint) in the first several tanks to provide a consistent reference frame for reporting of inspection results.

1P	1C	18
2P	2C	28
4P		48
5P	5C	
	6C	-

Figure 7. Tanks Used in Experiment Two.

The same criteria were used for marker selection as in the first experiment. The intent was that the markers be roughly as easy or hard to detect as cracks, not that they necessarily look like cracks. An additional objective was that a marker, once detected, could be easily identified by an inspector as indeed being a marker. The tanks used in this experiment were coated; brown electrical tape approximately 1/8 inch wide proved to be the marker material that best met the selection criteria. Markers were placed on an ad hoc basis in realistic locations (that is, locations where cracking might have been anticipated) in seven of the 11 tanks. Only two to four markers were placed in each tank to avoid the change in inspection strategy that was observed in Experiment 1. Marker lengths ranged from 25 mm to 150 mm. A total of 24 markers were placed; two of them were not present during the follow-up inspection. The remaining 22 markers are used in analyzing the results of Experiment Two. Table 8 shows the number of markers in each tank; Table 9 shows the number of markers of each length.

Tank								48	5P	5C	6C
Number of Markers	3	4	2	4	4	3	0	2	0	0	0

Table 8. Number of Markers by Tank, Experiment Two.

Length, mm	50	75	100	125	150
Number of markers	7	4	2	5	2

Table 9. Number of Markers by Length, Experiment Two.

3.5 The Experiment

U.C. Berkeley researchers served as coordinators for the experiment. The shipyard provided a place to change and to eat lunch, but left the researchers and inspectors alone to carry out the experiment independently. As noted above, the weather during the experiment was hot and humid.

3.5.1 Participants

The seven inspectors who took part in this project were all actively involved in inspection work at the time the experiment was conducted. Their backgrounds and experience, as reported on the post-inspection questionnaire, are summarized in Table 10; questionnaire responses are included in Appendix A. The inspectors in this experiment had considerably more experience with ships of the same class as the one being inspected than was the case for the inspectors in the first experiment. Three of the inspectors reported having carried out more than 65 hours of inspection work in the previous week; two of these reported carrying out more than 80 hours during this period.

	Inspector and affiliation								
	Α	В	С	D	E	F	G		
	CLASS	USCG	COMM	COMM	USCG	COMM	COMM		
Inspection hours in previous week	65-80	<50	<50	<50	<50	>80	>80		
Years of inspection experience	5-8	<2	5-8	5-8	5-8	>9	5-8		
Prior inspections of Ship 2	1	0	0	0	0		>3		
Sister ship(s) inspections	>5	1 or 2	>5	3 or 4	1 or 2	>5	>5		
Inspection training (years)	1/2 - 1	< 1/2	>2	1/2 -1	>2	>2	>2		
Past inspection reports reviewed?	no	yes	no	no	no	no	no		

USCG = U, S, Coast Guard; CLASS = Classification Society; COMM = Commercial Inspector.

Table 10. Inspector's Experience, Experiment Two

3.5.2 Tank Inspection

For each tank, six of the seven inspectors carried out a visual inspection without disturbing the tank's condition. Thus, these inspectors were able to report visible defects, markers, and suspect areas (areas that they would have scraped under normal circumstances). The seventh inspector (the last one in the tank) carried out a visual inspection including scraping; the seventh inspector was thus able to determine whether a suspect area did indeed contain a defect. The seventh inspector, therefore, reported defects (visible and scraped) and markers.

A tank inspection schedule was developed to rotate inspectors through groups of tanks so that each inspector would be the "scraper" (that is, the seventh inspector) for one or two tanks, with appropriate rest periods. Two inspectors were allowed in the wing tanks simultaneously; in the center tanks, two, three, or four inspectors worked simultaneously.

Inspectors were shown a sample marker upon entering the first tank, and were instructed to carry out the inspection as they normally would, but to record visible defects, suspect areas, and markers. The seventh inspector was instructed to carry out a standard inspection (including the cleaning of any suspect areas) and to record defects and markers.

During rest breaks, each inspector was debriefed by one of the researchers, who recorded location, type (visible defect, suspect area, marker), and length (if visible defect or marker) for each area reported.

Several of the commercial inspectors climbed throughout the tank and thus recorded defects and suspect areas that were not accessible to the other inspectors.

3.5.3 Follow-up Inspection

In the evening following the initial inspections, the coordinators combined the results from the individual inspectors to form a master list. To reduce the chances of misinterpreting the inspection reports, the location and description of each fracture and suspect area were included in the same words as reported by the inspectors during the experiment.

Follow-up inspections were carried out by two of the commercial inspectors, those with the most tank inspection experience, after the initial inspections were completed. One U.C. researcher accompanied each inspector and read out the list of visible defects, suspect areas, and markers from the baseline data set (the combination of all items recorded by all inspectors). For visible defects and markers, the follow-up inspector confirmed that the recorded defect or marker was indeed present. For suspect areas, the follow-up inspector gave his opinion as to whether or not the area was indeed suspect, and then scraped the area to determine if a fracture was present.

3.6 Results

Results for all inspectors are available for ten of the eleven tanks inspected. No results are available for Inspectors B and C in Tank 2C. Inspector B was the designated scraper for Tank 2C. However, rather than record defects and markers on a paper, Inspector B marked the areas in the tank. Time did not permit a review of the tank to compile a written record of the defects and markers found. Inspector C did not inspect Tank 2C. Therefore, detection rates for defects, suspect areas, and markers found in Tank 2C are calculated using five as the total number of inspectors (rather than seven for the other tanks).

Eight fractures were found in accessible areas (two in Tank 2C; one in Tank 5S; five in Tank 6C). Detection rates for these fractures ranged from 0.14 (found by one of seven inspectors) to 0.86 (found by all seven inspectors). Four additional fractures were found by at least one commercial inspector in areas that were inaccessible without climbing. However, it is not known how many of the commercial inspectors climbed in each tank, so detection rates cannot be reported for these cracks.

Of the 24 markers initially placed, the positions of 22 could be verified at the end of the experiment. For these 22 markers, detection rates ranged from 0.00 (four of the markers were not found by any of the seven inspectors) to 0.86 (two of the markers were found by six of seven inspectors).

Buckling was reported at 21 locations. The instructions did not specifically ask inspectors to report buckling, and most of the buckling was reported by only one inspector. Therefore, buckling is not considered in the analysis of results.

During the follow-up inspections, 95 of the reported locations were considered to be suspect by the follow-up inspector after they were pointed out. However, 68% of these locations were reported by only one inspector (that is, the other inspectors did not think that the area was suspect during the initial inspection).

Complete results from the inspections of Ship Two are included in Appendix C. A qualitative assessment of the experiment is provided next, followed by a quantitative analysis of detection rate and the factors that affect it.

As has been stated often in the literature, the size of tankers (and other structures) is such that an inspector does not thoroughly inspect the entire structure. Instead, the inspector scans the structure as a whole and then more carefully inspects critical areas — areas in which problems are anticipated. It would therefore be reasonable to expect that detection rates would be higher

for defects in critical areas. Two members of the Project Technical Committee for this project reviewed the list of fractures, markers, and suspect areas to identify those that could be considered critical. This information is used in the quantitative analysis section below.

3.6.1 Qualitative Analysis

All the inspectors seemed highly motivated to do a thorough job of inspection during the experiment. However, there were obvious differences in the physical condition and agility of the inspectors. Inspector A reported that he had a history of back problems, but these did not seem to affect his mobility in the tank. Inspector B had a much harder time negotiating the tanks than the other inspectors. Inspector E had sustained a cut on one leg the evening before the second day of inspection. The cut reopened part way through the second day of inspections; Inspector E completed the experiment nonetheless.

The presence of markers did not appear to cause the inspectors to modify their inspection strategy.

3.6.2 Quantitative Analysis

3.6.2.1 Vessel Factors

Of the vessel factors shown in Figure 1, only the defect factors vary in this experiment. There are, in effect, three kinds of "defects" reported: visible fractures, markers, and suspect areas. For visible fractures and markers, the effect on detection rate of size and type (critical or non-critical) can be examined. For suspect areas, only the effect of type can be examined.

Of the eight visible fractures, six were considered to be critical by at least one reviewer. Only these six fractures are included in the quantitative analysis. Detection rates for these fractures ranged from 0.20 (one of five inspectors) to 0.86 (six of seven inspectors). Figure 8 shows detection rate vs. length for the six fractures considered critical. In general, there is an increase in detection rate with length. This is clear when the mean detection rate for the four inch fractures is considered. The overall detection rate for these fractures (that is, the average of the detection rate for each individual fractures) was 0.60. The average detection rate for the two non-critical fractures was 0.29.

The locations of all 22 markers were considered to be critical by at least one reviewer. As noted above, marker detection rates ranged from 0.00 to 0.86. Figure 9 shows detection rate vs. length for the markers. In general, there is an increase in detection rate with length. This is more clearly shown in Figure 10, where the mean detection rate for each marker length is plotted. However, a linear regression on the marker data shows only a slight correlation ($R^2 = 0.094$), due to the broad range of observed detection rates within each marker length. Figure 11 shows mean marker and critical fracture detection rates; for this experiment, markers appear to yield detection rates that are comparable to or slightly lower than those of critical fractures. Table 11 shows fracture and marker detection rates by length for each inspector.

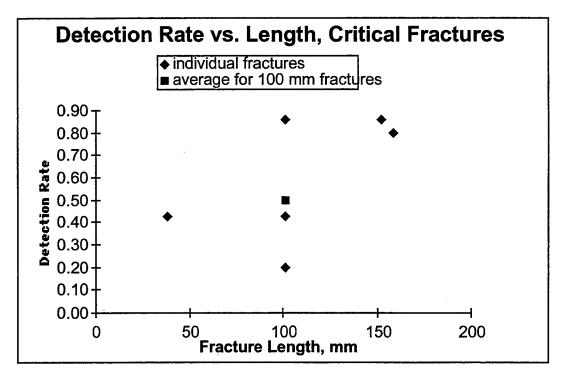


Figure 8. Detection Rate vs. Fracture Length, Experiment Two.

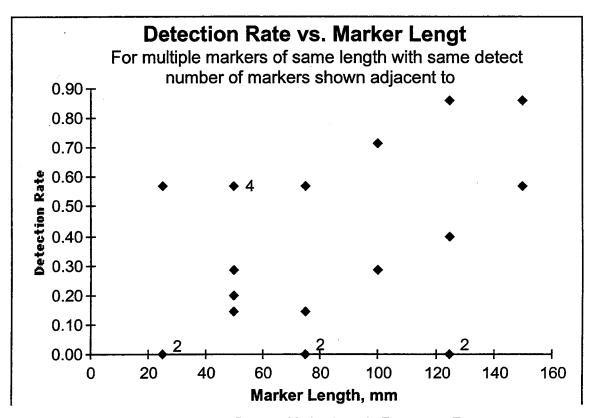


Figure 9. Detection Rate vs. Marker Length, Experiment Two

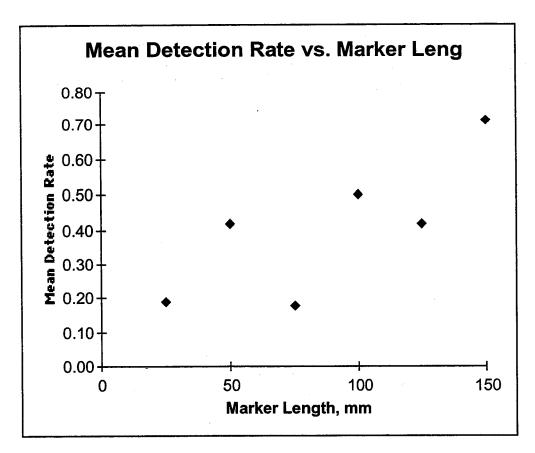


Figure 10: Mean Detection Rates vs. Marker Length, Experiment Two

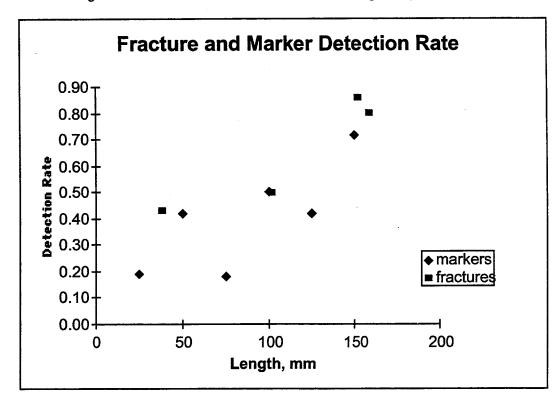


Figure 11. Detection Rates for Fractures and Markers, Experiment Two.

		Inspector and affiliation						
		A	В	С	D	E	F	G
		CLASS	USCG	COMM	COMM	USCG	СОММ	COMM
Fractu	res			Fractur	e Detection	n Rate		
Length, mm		x	= did not i	nspect; see	note belov	N		
40	1	0	0	0	1	0	1	1
100	3	.33	0.5	0.5	0.67	0.33	0.67	0.67
150	1	1	1	1	1	0	1	1
160	1	1	x	X	1	0	1	1
Mean detec	Mean detection rate:		0.5	0.5	0.83	0.17	0.83	0.83
Markers								
Length, mm	number			Marke	r Detectio	n Rate		
25	3	0	0	0.33	0.33	0	0.33	0.33
50	7	0	0.14	0.71	0.71	0.14	0.57	0.57
75	4	0	0.25	0.25	0.25	0.25	0	0.25
100	2	0	0.50	0.50	1	0	0.50	. 1
125	4	0.25	0.25	0.25	0.25	0.5	0.25	0.25
150	2	0.50	0.50	1	1	0	1	1
Mean detec	tion rate:	0.09	0.23	0.50	0.55	0.18	0.41	0.50

USCG = U. S. Coast Guard; CLASS = Classification Society; COMM = Commercial Inspector.

note: Tank 2C contained two factures (100 mm, 150 mm). Inspectors B and C did not inspect Tank 2C. Detection rates at 100 mm for these inspectors are based on two fractures only.

Table 11. Fracture and Marker Detection Rates, Experiment Two.

Of the 95 suspect locations, 18 were not considered to be critical by reviewers. The mean detection rate for these 18 areas was 0.20. For the remaining 77 areas, which were considered critical by at least one reviewer, the mean detection rate was 0.24. The mean detection rate for the 23 suspect areas that were considered critical by both reviewers was 0.30. For this experiment, the detection rate appears to be greater for fractures and suspect areas that are considered critical than for those that are not viewed as critical.

3.6.2.2 Inspector Factors

The inspector factors shown in Figure 1 include factors related to experience (overall experience, experience with the particular vessel, training) and factors related to the inspector's current situation (fatigue and motivation). The purpose of an inspection Questionnaire responses allow an investigation of the effect of the experience factors. The only information regarding the motivation of the inspectors is through the researchers' observations, summarized in Section 3.6.1.

Table 12 presents the available measures of experience along with the detection rate for each inspector. There are no clear relationships between the experience measures and detection rate. However, the inspectors with noticeable physical difficulty (B) or injury (A, E) had lower detection rates than the other inspectors. The most evident relationship is between the inspector's organization and detection rate: the commercial inspectors (C, D, F, G) had high detection rates; the USCG inspectors (B, E) had low detection rates. These inspectors also had less experience with sister ships than did the other inspectors. Inspector A had a very low marker detection rate.

•	Inspector and affiliation						
	Α	В	С	D	E	F	G
	CLASS	USCG	COMM	COMM	USCG	COMM	COMM
Inspection hours in previous week	65-80	<50	<50	<50	<50	>80	>80
Years of inspection experience	5-8	<2	5-8	5-8	5-8	>9	5-8
Prior inspections of Ship 2	. 1	0	0	0	0		>3
Sister ship(s) inspections	>5	1 or 2	>5	3 or 4	1 or 2	>5	>5
Inspection training (years)	1/2 to 1	< 1/2	>2	1/2 to 1	>2	>2	>2
Past inspection reports reviewed?	no	yes	no	no	no	no	no
Average time in tank, minutes	39	49	43	37	41	33	37
Critical Fracture Detection Rate	0.50	0.50	0.50	0.83	0.17	0.83	0.83
Marker Detection Rate	0.09	0.23	0.50	0.55	0.18	0.41	0.50
Suspect Area Detection Rate	0.21	0.43	0.10	0.32	0.22	0.12	0.27

USCG = U. S. Coast Guard; CLASS = Classification Society; COMM = Commercial Inspector.

Table 12. Inspector Experience and Detection Rates, Experiment Two.

3.6.2.3 Environment Factors

Of the environment factors shown in Figure 1, only inspection strategy, time available, and inspection type & objective varied among inspectors in this experiment. No difference in strategy was observed among the seven inspectors. There is a slight inverse relationship between time in tank and detection rate; those inspectors who spent, on average, less time in the tank had higher detection rates.

The inspectors who participated in this experiment came from three different types of organizations: a regulatory agency (USCG), a classification society, and commercial inspection firm. These organizations typically carry out different types of inspections with different objectives. For example, the primary role of regulatory agency and classification society inspectors is to verify problem areas identified by the owner/operator's inspection. Thus, it is reasonable to expect that detection rates might differ for inspectors from different organizations. Table 12 shows that the marker detection rates of commercial inspectors are noticably better than those of the other inspectors. The fracture detection rates for commercial inspectors are also better than those of other inspectors, though the difference is not as significant as for markers. The suspect area detection rates for commercial inspectors are not noticably different from those of other inspectors.

Because the last inspector in the tank was allowed to scrape the tank, the set up for this experiment would have allowed pure comparison of the scraper's performance had more fractures been found upon scraping. However, with most of the fractures visible without scraping, these is insufficient information to compare the performance of the "scraper" with that of the follow-up inspector.

3.7 Summary of Results of Experiment Two

Experiment Two demonstrated yet again that it is possible that an in situ experiment will indeed yield far fewer defects than anticipated, making markers a necessity if meaningful quantities of data are to be collected. The use of markers in Experiment Two was much more successful than was the case in Experiment One. The limited number of markers used in each tank did not divert the inspectors from their usual inspection strategy. Markers in critical locations were detected at roughly the same rates as critical cracks of the same length.

The fact that few fractures were found meant that, once again, the bulk of the data gathered was for suspect areas. Still, enough marker and fracture data were acquired to draw some tentative conclusions. As expected, average detection rates increase with crack/marker length. Lower detection rates were observed for inspectors with physical difficulties, with less sister ship experience, and who work for the USCG or ABS. It should be noted that the usual role of USCG or ABS inspectors is to verify the existence of problem areas and severity of fractures, but not necessarily to detect all fractures.

Commercial inspectors are typically the "front line" in inspection, hired by owners and operators to identify problem areas and critical fracture characteristics and number. For many purposes, commercial inspectors' performance is the most relevant measure of probability of detection. The fracture and marker detection rates of commercial inspectors are shown in Figure 12. For the limited data generated by this experiment, the two fractures and two markers with length of approximately 150 mm were detected by all four commercial inspectors. For shorter fractures and markers, detection rates were lower. Average detection rates for markers ranged from 0.19 (for four markers of 75 mm in length) to 0.75 (for two markers of 100 mm in length). The lowest observed fracture detection rate was 0.61 (for three fractures of 100 mm in length).

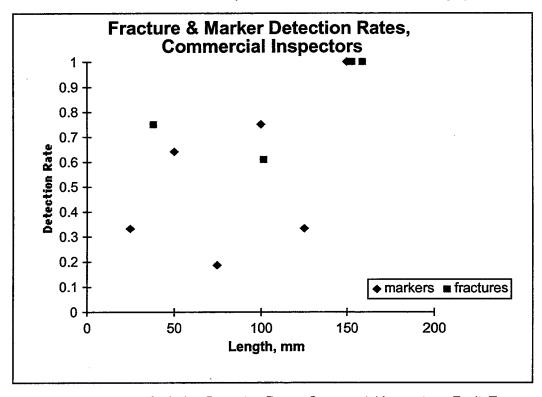


Figure 12. Fracture & Marker Detection Rates, Commercial Inspectors, Exp't. Two.

4. Summary and Conclusions

4.1 Summary

Two in situ inspection experiments were carried out as a part of this study. In each experiment, a number of experienced inspectors carried out visual inspections of an existing ship (each ship was out of service — for some other reason — at the time of the experiment). These in situ inspections provide a simulation of inspections done underway. The results of these inspections were aggregated into master lists of visible fractures, markers, and suspect areas. A follow-up inspection was carried out, guided by this list, to determine the true condition of the tank. Subsequent analysis of results was directed at determining whether marker detection rates are comparable to fracture detection rates, deducing which factors have a demonstrable impact on probability of detection, and observing levels and variability of probability of detection.

Due to the small number of fractures found in the first experiment and to the non-standard inspection strategy resulting from the large number of markers, the results of the first experiment provide little useful information (beyond ideas for improving the experimental protocol). The second experiment, however, yielded results that, while not statistically significant, do shed some light on the usefulness of in situ testing as a means of determining probability of detection, on the factors affecting probability of detection, and on probability of detection itself.

4.2 Conclusions Regarding Experimental Method

The initial concern that not enough fractures would be found to make an in situ experiment worthwhile was well founded. The owners of each of the ships used in this experiment were confident that many fractures would be found. In both cases, they were proven wrong. However, the mix of a few cracks and a few markers that was used in Experiment Two allowed extra information to be obtained without dramatically changing the inspection strategy used. The detection rate for markers was comparable to the detection rate for critical fractures. Therefore, in situ experiments should not be ruled out as a means of obtaining POD information. However, appropriate markers should be used for in situ experiments on structures whose condition is not already known.

In a tank with more fractures, assigning the last inspector as the "scraper" (as was done in Experiment 2) would allow additional information to be gleaned from the results.

Even with donated ship time, these in situ experiments are costly. The costs must be weight against the benefits of the information obtained.

4.3 Conclusions Regarding Factor Evaluation

Although statistically significant conclusions could not be drawn from the data generated by the in situ experiments, certain factors appear to be somewhat related to detection rate. Due to the unusual inspection strategy used in Experiment One, this discussion is based on the results of Experiment Two. As expected, detection rate appears to increase with increased defect or marker length. However, the scatter of detection rates at any given length is such that this relationship is not strong in a statistical sense.

Lower detection rates were observed for inspectors with physical difficulties, with less sister ship experience, and who work for the USCG or ABS (these inspectors normally verify only problem areas and severity of fractures). Higher detection rates were observed for commercial inspectors,

who are normally hired to indentify problem areas and the characteristics and number of fractures.

Higher detection rates were observed for defects and suspect areas that were considered by reviewers to be critical. This supports the notion than an experienced inspector pays attention to trouble spots. Higher detection rates were observed for commercial inpsectors than for other inspectors.

To make definitive statements about the effect of factors on detection rate, additional experiments would have to be conducted so that information is available for a greater number of fractures and markers.

4.4 Conclusions Regarding POD for Underway Inspection

It would be a mistake to draw far-reaching conclusions about POD for underway inspection from the limited information presented here. However, for the six fractures found in experiment two, detection rates for commercial inspectors averaged 0.75 (one at 0.50, three at 0.83). For the two fractures and two markers that were 150 mm or longer, detection rates for commercial inspectors were 1.00; every commercial inspector found each fracture or marker.

4.5 Recommendations for Further Work

Based on the results of Experiment Two, in situ experiments do have the potential to increase our knowledge of POD in tanker inspection. However, these experiments are expensive to carry out. It would be worthwhile to carry out additional experiments only if the results would lead to changes in design or maintenance practices. Prior to carrying out any additional experiments, current design and maintenance practices should be reviewed to see whether they would be changed if additional information on POD were to be developed.

5. References

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Appendix A:

Sample Questionnaire and Summary Results

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·				
	·			

10am #1

V E	:55EL:			DATE: _// & // /
1.	How many hours of inspe	ection work have you done	in the past seven days?	
	less than 50 hours	☐ 50 to 64 hours	☐ 65 to 80 hours	☐ more than 80 hours
2.	How many years of expe	rience do you have perfor	ming inspections on ships?	
	☐ less than 2 years	☐ 2 to 4 years	■ 5 to 8 years	☐ more than 9 years
3.	How much classroom a	nd in-field inspection traini	ng have you received duri	ng your career?
	☐ less than 6 months	☐ 6 months to 1 yr	1 to 2 years	☐ more than 2 years
4.	How may times have you	inspected vessels of the s	ame class as this ship?	
	□ none	one or two	☐ three or four	■ five or more
5.	Not including today's insp	pection, how many times h	ave you inspected this ves	sel in the past?
	none	☐ once	☐ twice	☐ three or more times
6.	Did you review reports	of previous inspections of	this vessel prior to today's	s inspection?
	□ yes	അ no		·.
7.	Did you review a detailed	d plan of areas to be inspe	cted (such as a CAIP) prio	r to today's inspection?
	□ yes	n o		•
8.	Where was the ship loca	ited while today's inspection	n was performed?	
	☐ underway	at dockside	☐ in dry-dock	
9.	If today's inspection was	performed underway, how	would you describe the se	ea condition?
	☐ calm	☐ moderate	☐ rough	not applicable .
10	. What type of access wa	s used during today's inspe	ection?	
	bottom walking	☐ rafting	☐ staging ;	☐ other (specify)
11	. How would you describ	e the ambient lighting ava	ilable in the tanks you insp	ected?
	poor poor	☐ fair	□ good	□ excellent ;
12	. How would you descril	be the lighting provided by	y your portable flashlight o	luring this inspection?
	poor	☐ adequate	☐ excellent	no flashlight used

4)

VES	SSEL:			DATE:
13.	How would you describe	the color of the coating us	sed in the tank?	
	dark dark	□ light	☐ no coating ·	*
14.	How would you describe	the tanks' cleanliness?		
	poor poor	☐ fair	□g∞d	□ excellent
15.	How would you describe	e the temperature in the t	ank during this inspection?	
	□ cold	moderate (comfortab	le)	□ hot
16.	How would you describe	e the ventilation in the tar	k during this inspection?	
	□ p∞r ·	☐ fair	≣ g∞d	□ excellent
17.	Did you have to wear a	a respirator while perform	ing this inspection?	
	☐ yes; please specify typ	pe	_	■ no
18.	Did you use protective	eyewear during this inspe	ction?	
	□ no	☐ yes, prescription glas	ses	glasses
19.	Please estimate the total	al time you were in the ta	nk(s) during this inspectio	n.
20.	How would you describe	e the amount of time avail	able to carry out the inspe	ction?
21.	☐ insufficient During this inspection, v	☐ limited, but acceptable Marker Taule what was the longest you		time was not a problem
	☐ less than 1 hour	☐ 1 to 2 .1/2 hours	2 1/2 to 4 hours	more than 5 hours
22.	In general, how would y	ou rate the preparation o	f the vessel for this inspec	ction?
	□ poor	fair .	□ good	excellent
23.	For what type of organia	zation were you conductin	g this inspection?	•
	regulatory agency	☐ classification society	□owner/operator	repair facility
24.	Please include any addit Marker tank: ex exams with have a past	ional comments you have forcise was not much more pattern to follow	about today's inspection in realistic. I usual background be a support of the sup	the space below. My Conquet Soutledge I issually

INSPECTOR QUESTIONNAIRE, PAGE 1

VE	ESSEL: <u>ISKOOKS K</u>	ANGE		DATE: <u>9/27/95</u>
1.	How many hours of inspec	ction work have you done i	n the past seven days?	
	☐ less than 50 hours	☑ 50 to 64 hours	☐ 65 to 80 hours	☐ more than 80 hours
2.	How many years of expen	rience do you have perforn	ning inspections on ships?	
	☐ less than 2 years	2 to 4 years	☐ 5 to 8 years	☐ more than 9 years
3.	How much classroom an	d in-field inspection trainir	ng have you received duri	ng your career?
	☐ less than 6 months	☐ 6 months to 1 yr	1 to 2 years	☐ more than 2 years
4.	How may times have you	inspected vessels of the sa	ame class as this ship?	
	none	one or two	☐ three or four	- ☐ five or more
5.	Not including today's insp	ection, how many times ha	ave you inspected this ves	sel in the past?
	☑ none	□ once	☐ twice	☐ three or more times
6.	Did you review reports o	f previous inspections of t	this vessel prior to today's	inspection?
	☐ yes	□ no		
7.	Did you review a detailed	plan of areas to be inspec	ted (such as a CAIP) prior	to today's inspection?
	□ yes	□ no		
8.	Where was the ship locat	ed while today's inspection	n was performed?	
	☐ underway	at dockside	☐ in dry-dock	
9.	If today's inspection was p	performed underway, how	would you describe the se	a condition?
	□ calm	☐ moderate	☐ rough	not applicable
10.	What type of access was	used during today's inspe	ction?	
	bottom walking	☐ rafting	☐ staging	other (specify)
11.	How would you describe	the ambient lighting avail	able in the tanks you inspe	ected?
	☐ poor	☐ fair	good	☐ excellent
12.	How would you describe	e the lighting provided by	your portable flashlight de	uring this inspection?
	□ poor	☐ adequate	☑ excellent	☐ no flashlight used

PLEASE TURN OVER AND COMPLETE ITEMS 13-24.

VES	SSEL: 1800KS	RANGE		DATE: <u>9/27/85</u>		
13.	How would you describe	the color of the coating us	ed in the tank?	OC WITH RECENT		
	☐ dark	□ light	no coating REPAIR			
14.	How would you describe	e the tanks' cleanliness?	ARRA	S CUERR DAFK.		
	☑ poor	☐ fair	□g∞d	□ excellent		
15.	How would you describ	e the temperature in the ta	ank during this inspection?			
	□ cold	moderate (comfortable)	e)	□ hot		
16.	How would you describ	e the ventilation in the tan	k during this inspection?			
	□ poor	☐ fair	☑ good	□ excellent		
17.	Did you have to wear	a respirator while performi	ing this inspection?			
	☐ yes; please specify ty	pe	_	☑no		
18.	8. Did you use protective eyewear during this inspection?					
	□ no	yes, prescription glas	ses	☐ yes, protective glasses		
19.	Please estimate the to	tal time you were in the ta	nk(s) during this inspectio	n.		
			_ minutes			
20.	How would you describ	e the amount of time availa	able to carry out the inspe	ction?		
	□ insufficient	☐ limited, but acceptable	e	time was not a problem		
21.	During this inspection,	what was the longest you	had to work without a brea	ak?		
	☐ less than 1 hour	☐ 1 to 2 1/2 hours	2 1/2 to 4 hours	☐ more than 5 hours		
22.	In general, how would	you rate the preparation o	f the vessel for this inspec	ction?		
	□ poor	☐ fair	□ good	☐ excellent		
23.	For what type of organ	ization were you conductin	g this inspection?	•		
	regulatory agency	☐ classification society	□owner/operator	☐ repair facility		
24	Please include any addi	itional comments you have	about today's inspection in	the space below.		

VE	SSEL: BROOKS RA	NG E		DATE: 9/27
1.	How many hours of inspec	ction work have you done in	n the past seven days?	
	☑ less than 50 hours	☐ 50 to 64 hours	☐ 65 to 80 hours	☐ more than 80 hours
2.	How many years of exper	rience do you have perform	ning inspections on ships?	•
	প্র less than 2 years	☐ 2 to 4 years	☐ 5 to 8 years	☐ more than 9 years
3.	How much classroom an	d in-field inspection trainin	g have you received durin	ng your career?
	区 less than 6 months	☐ 6 months to 1 yr	☐ 1 to 2 years	☐ more than 2 years
4.	How may times have you	inspected vessels of the sa	me class as this ship?	
	☑ none	☐ one or two	☐ three or four	T five or more
5.	Not including today's insp	ection, how many times ha	ave you inspected this vess	sel in the past?
	none	☐ once	☐ twice	☐ three or more times
6.	Did you review reports o	f previous inspections of t	his vessel prior to today's	inspection?
	☐ yes	 no		
7.	Did you review a detailed	plan of areas to be inspec	ted (such as a CAIP) prior	to today's inspection?
	□ yes	⊠ no		
8.	Where was the ship locat	ed while today's inspection	was performed?	
	☐ underway	🔀 at dockside	☐ in dry-dock	
9.	If today's inspection was p	performed underway, how	would you describe the se	a condition?
	□ calm	☐ moderate	☐ rough	not applicable
10.	What type of access was	s used during today's inspec	ction?	
	☑ bottom walking	☐ rafting	☐ staging	□ other (specify)
11.	How would you describe	the ambient lighting availa	able in the tanks you inspe	ected?
	□ poor	(fair	□ gccd	□ excellent
12.	How would you describ	e the lighting provided by	your portable flashlight d	uring this inspection?
	poor ·	⊠.adequate	□ excellent	☐ no flashlight used

VESSEL:	520014	KANGE.		DATE: 1/27/95
13. How v	would you describ	e the color of the co	ating used in the tank?	
□ dar	k	□ light	☐ no coating	ONLY ON BOTTOM
14. How 1	would you describ	oe the tanks' cleanlin	ess?	
□р∞	r	☐ fair	Ægo∞d	☐ excellent
15. How	would you descri	be the temperature	in the tank during this insp	pection?
☐ colo		☑ moderate (co	mfortable)	□ hot
16. How	would you descri	be the ventilation in	the tank during this inspe	ection?
□ рос	or	⊠ fair	☐ good	☐ excellent
17. Did y	ou have to wear	a respirator while p	performing this inspection	?
☐ yes	; please specify t	ype		⊠no
18. Did y	ou use protective	e eyewear during thi	s inspection?	
⊠ no		☐ yes, prescripti	on glasses .	☐ yes, protective glasses
19. Pleas	se estimate the to	otal time you were in	n the tank(s) during this in	spection.
		440	minutes	
20. How	would you descri	be the amount of tim	ne available to carry out th	e inspection?
□ ins	sufficient	☑ limited, but ac	cceptable	time was not a problem
21. Durin	g this inspection,	what was the longe	est you had to work withou	t a break? 25 + 2 = 4.5
☐ les	s than 1 hour	☐ 1 to 2 1/2 ho	urs 2 1/2 to 4 ho	urs 🗹 4.5 🔲 more than 5 hours
22. In ge	neral, how would	you rate the prepar	ration of the vessel for this	s inspection?
□рос	or .	☐ fair	□ g∞od	⊠ excellent
23. For v	what type of orga	nization were you co	onducting this inspection?	
⊠ reg	julatory agency	☐ classification	society Downer/operato	or
24. Pleas 况: . 工	te include any add	ditional comments you have inspected to the second	u have about today's insper	ever control

VE	SSEL: <u>S(OOKS)</u>	Range_		DATE:
1.	How many hours of inspec	ction work have you done i	n the past seven days?	
	☑ less than 50 hours	☐ 50 to 64 hours	☐ 65 to 80 hours	☐ more than 80 hours
2.	How many years of exper	rience do you have perforn	ning inspections on ships?	
	☐ less than 2 years	☐ 2 to 4 years	☑ 5 to 8 years	☐ more than 9 years
3.	How much classroom an	d in-field inspection trainir	ng have you received duri	ng your career?
	☐ less than 6 months	☑ 6 months to 1 yr	☐ 1 to 2 years	☐ more than 2 years
4.	How may times have you	inspected vessels of the sa	me class as this ship?	
	☑ none	☐ one or two	☐ three or four	☐ five or more
5.	Not including today's insp	ection, how many times ha	ave you inspected this ves	sel in the past?
	∑ none	□ once	☐ twice	☐ three or more times
6.	Did you review reports o	f previous inspections of t	this vessel prior to today's	inspection?
	☐ yes	区 no		
7.	Did you review a detailed	plan of areas to be inspec	eted (such as a CAIP) prior	to today's inspection?
	☐ yes	™ no		
8.	Where was the ship locat	ed while today's inspection	was performed?	
	underway	য়ে at dockside	☐ in dry-dock	
9.	If today's inspection was p	performed underway, how	would you describe the se	a condition?
	□ calm	☐ moderate	☐ rough	🖾 not applicable
10.	What type of access was	s used during today's inspe	ction?	
		☐ rafting	☐ staging	□ other (specify)
11.	How would you describe	the ambient lighting avail	able in the tanks you inspe	ected?
	☑ poor	☐ fair	□good	excellent
12.	How would you describe	e the lighting provided by	your portable flashlight de	uring this inspection?
	₩ poor	☐ adequate	☐ excellent	☐ no flashlight used

□ excellent on? □ hot ? □ excellent □ a
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⊠ no
<u> </u>
yes, protective glasses
etion.
pection?
☐ time was not a problem
reak?
☐ more than 5 hours
pection?
☐ excellent
☐ repair facility
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ut. Vin go-eg. I didn

VE	ssel: <u>Brooks</u> R	ANGE	TIONNAINE, PAGE 1	DATE: <u>9-27-9</u> 5
1.	How many hours of inspec	ction work have you done i	n the past seven days?	
	less than 50 hours	☑ 50 to 64 hours	☐ 65 to 80 hours	☐ more than 80 hours
2.	How many years of exper	ience do you have perform	ning inspections on ships?	
	☐ less than 2 years	☐ 2 to 4 years	☐ 5 to 8 years	☑ more than 9 years
3.	How much classroom and	d in-field inspection training	ng have you received durin	ng your career?
	☐ less than 6 months	☐ 6 months to 1 yr	☐ 1 to 2 years	more than 2 years
4.	How may times have you i	inspected vessels of the sa	me class as this ship?	
	none	☐ one or two	☐ three or four	five or more
5.	Not including today's insp	ection, how many times ha	ave you inspected this vess	sel in the past?
	none	☐ once	☐ twice	three or more times
6.	Did you review reports of	f previous inspections of t	his vessel prior to today's	inspection?
	□ yes	⊠no		
7.	Did you review a detailed	plan of areas to be inspec	ted (such as a CAIP) prior	to today's inspection?
	☐ yes	⊅ no		
8.	Where was the ship locate	ed while today's inspection	was performed?	
	underway	at dockside	☐ in dry-dock	
9.	If today's inspection was p	performed underway, how	would you describe the se	a condition?
	⊠_calm	☐ moderate	☐ rough	☐ not applicable
10.	What type of access was	used during today's inspec	ction?	
	bottom walking	☐ rafting	☐ staging	□ other (specify)
11.	How would you describe	the ambient lighting availa	able in the tanks you inspe	ected?
	□ poor	🏿 fair	good	□ excellent
12.	How would you describe	e the lighting provided by	your portable flashlight de	uring this inspection?
	□ poor	□ adequate	□ excellent	☐ no flashlight used

PLEASE TURN OVER AND COMPLETE ITEMS 13-24.

VESSEL: <u>DROO</u>	KS RANGE		DATE: <u>7-27-23</u>
13. How would you	describe the color of the co	ating used in the tank?	
☐ dark	⊠ light	no coating	
14. How would you	describe the tanks' cleanling	ess?	
□ p∞or	☐ fair	∑ ∑ g∞∞d	□ excellent
15. How would you	describe the temperature	in the tank during this insp	ection?
□ cold	moderate (con	mfortable)	☐ hot
16. How would you	u describe the ventilation in		ction?
□ poor	☐ fair	₩ good	□ excellent
17. Did you have	to wear a respirator while p	performing this inspection?	
☐ yes; please s	specify type		⋈ no
18. Did you use p	rotective eyewear during thi	s inspection?	
₩ no	☐ yes, prescript	on glasses	yes, protective glasses
19. Please estima	te the total time you were i	n the tank(s) during this in	spection.
	420	minutes	
20. How would you	u describe the amount of tin	ne available to carry out th	e inspection?
☐ insufficient	limited, but a	cceptable	☐ time was not a problem
21. During this ins	spection, what was the longe		
☐ less than 1	hour 🕱 1 to 2 1/2 ho	ours 2 1/2 to 4 ho	urs
22. In general, ho	w would you rate the prepa	ration of the vessel for this	s inspection?
□ poor	☐ fair	good	□ excellent
23. For what type	of organization were you c	onducting this inspection?	
☐ regulatory a	gency Classification	society Downer/operate	or
24. Please include	any additional comments yo	ou have about today's inspe	ection in the space below.



VE	ssel: <u>Brooks</u> R	auge_		DATE: 9-27-95							
1.	How many hours of inspec	ction work have you done i	n the past seven days?								
	☐ less than 50 hours		☐ 65 to 80 hours	☐ more than 80 hours							
2.	How many years of exper	ience do you have perforn	ning inspections on ships?								
	☐ less than 2 years	☐ 2 to 4 years	☑ 5 to 8 years	☐ more than 9 years							
3.	How much classroom an	d in-field inspection trainir	ng have you received during	ng your career?							
	☐ less than 6 months	☑ 6 months to 1 yr	☐ 1 to 2 years	☐ more than 2 years							
4.	How may times have you	inspected vessels of the sa	me class as this ship?								
	none	☐ one or two	☐ three or four	☑ five or more							
5.	Not including today's insp	ection, how many times ha	ave you inspected this ves	sel in the past?							
	none	□ once ·	☐ twice	☑ three or more times							
6.	Did you review reports o	f previous inspections of	this vessel prior to today's	inspection?							
	□ yes	⊠ no	•	·.							
7.	Did you review a detailed	plan of areas to be inspec	cted (such as a CAIP) prior	to today's inspection?							
	□ yes	⊠ no									
8.	Where was the ship locat	vas the ship located while today's inspection was performed?									
	☐ underway	☑ at dockside	☐ in dry-dock								
9.	If today's inspection was	performed underway, how	would you describe the se	a condition?							
	□ calm	☐ moderate	□ rough	☑ not applicable .							
10	. What type of access was	s used during today's inspe	ection?	•							
	☑ bottom walking	☐ rafting	☐ staging	□ other (specify)							
11	. How would you describe	the ambient lighting avail	lable in the tanks you insp	ected?							
	☑ poor	. 🗆 fair	□ g∞d	☐ excellent							
12	. How would you describ	e the lighting provided by	your portable flashlight d	uring this inspection?							
	□ poor	☑ adequate	☐ excellent	no flashlight used							

VESSEL: Brooks	Range		DATE: <u>9-27-95</u>
13. How would you describ	pe the color of the coating u	sed in the tank?	
☐ dark	☑ light	☐ no coating	
14. How would you descri	be the tanks' cleanliness?		
□ poor	☑ fair	□g∞d	□ excellent
15. How would you descri	ibe the temperature in the	tank during this inspection	n?
□ cold	☑ moderate (comfortab	ole)	☐ hot
16. How would you descr	ibe the ventilation in the ta	nk during this inspection?	?
□ poor	☐ fair	☑ good	☐ excellent
17. Did you have to wear	r a respirator while perform	ning this inspection?	
☐ yes; please specify t	ype		⊠ no
18. Did you use protective	e eyewear during this inspe	ection?	
⊠ no	☐ yes, prescription glas	sses	☐ yes, protective glasses
19. Please estimate the t	otal time you were in the ta	ank(s) during this inspect	ion.
	3 Tanks 120 rach	_ minutes	
20. How would you descri	be the amount of time avai	lable to carry out the insp	pection?
☐ insufficient	☑ limited, but acceptab	le	☐ time was not a problem
21. During this inspection	, what was the longest you	had to work without a br	eak?
☐ less than 1 hour	☐ 1 to 2 1/2 hours	☑ 2 1/2 to 4 hours	☐ more than 5 hours
22. In general, how would	d you rate the preparation of	of the vessel for this insp	ection?
□ poor	☐ fair	⊠ good	excellent
23. For what type of orga	nization were you conducti	ng this inspection?	
☐ regulatory agency	☐ classification society	⊠owner/operator	☐ repair facility
24 Please include any ad-	ditional comments you have	about today's inspection	in the space below.

INSPECTOR QUESTIONNAIRE, PAGE 1 VESSEL: BROOKS RANGE

_	,			DATE: (27/1/13
1	. How many hours of ins	pection work have you don	ne in the past seven days?	
	☐ less than 50 hours	☐ 50 to 64 hours	65 to 80 hours	☐ more than 80 hours
2	. How many years of exp	perience do you have perfo	orming inspections on ships	
	☐ less than 2 years	☐ 2 to 4 years	☐ 5 to 8 years	more than 9 years
3.	How much classroom	and in-field inspection trai	ning have you received du	
	less than 6 months	☐ 6 months to 1 yr	☐ 1 to 2 years	☐ more than 2 years
4.	How may times have yo	u inspected vessels of the	samē class as this ship?	·
	none	a one or two	☐ three or four	☐ five or more
5.	Not including today's ins	spection, how many times	have you inspected this ve	ssel in the past?
	none	□ once	☐ twice	☐ three or more times
6.	Did you review reports	of previous inspections of	f this vessel prior to today	's inspection?
	□ yes	n o		
7.	Did you review a detaile	d plan of areas to be inspe	ected (such as a CAIP) pric	or to today's inspection?
	□ yes	m no	•	
8.	Where was the ship loca	ated while today's inspection	on was performed?	
	☐ underway	≝ ⁻at dockside	☐ in dry-dock	
€.	If today's inspection was	performed underway, how	would you describe the se	ea condition?
	□ calm	☐ moderate	□ rough	a not applicable
10.	What type of access wa	s used during today's inspe	ection?	
	. bottom walking	☐ rafting	☐ staging	other (specify)
1.	How would you describe	e the ambient lighting avail	lable in the tanks you inspe	ected?
	p oor	☐ fair	□ g∞d	□ excellent
2.	How would you describ	e the lighting provided by	your portable flashlight du	uring this inspection?
į	□ poor	☐ adequate	excellent	☐ no flashlight used

PLEASE TURN OVER AND COMPLETE ITEMS 13-24.

	INSPECTOR QUEST	MONNAIRE, PAGE 2	//_
VESSEL: BROOKS	RANGE		DATE: 27/9/95
13. How would you describ	e the color of the coating use	ed in the tank?	
dark dark	☐ light	no coating	
14. How would you describ	be the tanks' cleanliness?		
p oor	☐ fair	□ good	☐ excellent
15. How would you descri	ibe the temperature in the ta	ank during this inspection	?
□ cold	moderate (comfortable	e)	☐ hot
16. How would you descr	ibe the ventilation in the tan	k during this inspection?	
□ poor	☐ fair	□ g∞d	excellent
17. Did you have to wea	r a respirator while performi	ng this inspection?	
☐ yes; please specify	type	-	™ no
18. Did you use protectiv	e eyewear during this inspec	ction?	
□ no	₩ yes, prescription glas	ses	☐ yes, protective glasses
19. Please estimate the 1	total time you were in the ta	nk(s) during this inspecti _ minutes	on.
20. How would you descr	ibe the amount of time availa	able to carry out the insp	ection?
☐ insufficient	limited, but acceptable	le	☐ time was not a problem
21. During this inspection	, what was the longest you	had to work without a bro	eak?
☐ less than 1 hour	☐ 1 to 2 1/2 hours	🗯 2 1/2 to 4 hours	☐ more than 5 hours
22. In general, how woul	d you rate the preparation o	f the vessel for this insp	ection?
□ poor	a fair	□g∞d	☐ excellent
23. For what type of orga	anization were you conductir	ng this inspection?	
☐ regulatory agency	classification society	□owner/operator	☐ repair facility
24. Please include any ac	dditional comments you have	about today's inspection	in the space below.

VE	ESSEL: <u>Knibrii</u> Co	V. LOS 11 F		DATE: 7/24/96
1.	How many hours of insp	pection work have you dor	ne in the past seven days?	
	B cD € O less than 50 hours	O 50 to 64 hours	A O 65 to 80 hours	FG o more than 80 hours
2.	How many years of exp	perience do you have perf	orming inspections on ship	os?
	B O less than 2 years	O 2 to 4 years	ACDES O 5 to 8 years	F O more than 9 years
2	·	·	-	•
٥.	B	AD	ining have you received o	_
	O less than 6 months	O 6 months to 1 yr	O 1 to 2 years	$C \in F \subseteq C$ O more than 2 years
4.	How may times have yo	u inspected vessels of the	_	
	O none	BE	D O three or four	ACFG
	o none	O one or two	O three or four	O five or more
5.		_	have you inspected this v	vessel in the past?
	BCDEF Onone	A O once	O twice	C three or more times
_	D . 1			
6.			of this vessel prior to toda	ay's inspection?
	B o yes	ACDE FG Ono	•	
	- ,	55		
7.	Did you review a detaile	ed plan of areas to be insp	pected (such as a CAIP) p	rior to today's inspection?
	G	ABCDEF		
	O yes	O no		
8.	Where was the ship loc	ated while today's inspect	tion was performed?	
	O updopuou	ABCDEF6	O im alou aloula	
	O underway	O at dockside	O in dry-dock	
9.	If today's inspection was	s performed underway, ho	w would you describe the	sea condition?
	CC.			ABDEF
	o calm	O moderate	O rough	o not applicable
10.	What type of access wa	as used during today's ins	pection?	
	ABCDEにも O bottom walking	O rafting	O staging	o other (specify)
11.	How would you describ	be the ambient lighting av	ailable in the tanks you in	spected?
	ADF	B & O fair	C. € O good	
	O poor	O fair	0 good	O excellent
12.	How would you descri		by your portable flashlight	t during this inspection?
	O poor	ABDEF O adequate	૯ લ O excellent	O no flooblisht wood
	o pool	o avequate	O EXCENEIII	O no flashlight used

VES	SSEL: Kuibat Conf	POSITE		DATE:
13.	How would you describe	the color of the coating us	sed in the tank?	
ī	3 O dark	ACDEF G O light	O no coating	
14.	How would you describe	the tanks' cleanliness?		
	B O poor	A O fair	CDE G	C excellent
15.	How would you describe	e the temperature in the t	ank during this inspection?	?
	o cold	O moderate (comfortable	e)	ABCDEFG o hot
16.	How would you describ	e the ventilation in the tar		
	A O poor	O fair	CEF6 Ogood	O excellent
17.	Did you have to wear a	a respirator while perform	ing this inspection?	
	O yes; please specify type	e	_	ABCDEFS Ono
18.	Did you use protective	eyewear during this inspe	ction?	
	O NO A B C D E F B	O yes, prescription glass	ses	O yes, protective glasses
19.	Please estimate the total	al time you were in the ta	nk(s) during this inspectio	n.
20.	How would you describe	e the amount of time availa	able to carry out the inspe	ction?
	O insufficient	しりょう O limited, but acceptable	ARF of time was not a problen	n
21.	During this inspection, v	vhat was the longest you	had to work without a brea	ak?
	O less than 1 hour	ABCDF 6 O 1 to 2 1/2 hours	O 2 1/2 to 4 hours	o more than 5 hours
22.	In general, how would y	ou rate the preparation of	f the vessel for this inspec	etion?
	O poor	D fair	ACEF 6 Ogood	O excellent
23.	For what type of organia	zation were you conductin	g this inspection?	
	多ピ O regulatory agency	A o classification society	Oowner/operator	O repair facility
24.	Please include any addit { inspection should be the ad a trumind to the 6 and and of conting	ional comments you have a broken up one on perior le n toll on ingrectors que sometiment of it	about today's inspection in doldays (moinings county county) accusible inpicts st	the space below. I evaniss) obob-1000, 1500-220 Intel be able to ese clears gear

Appendix B:

Reported Areas, Experiment 1

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	·			
				•

Tank: 3S Note: X = No length given

Reported Lengths By Team

Frame	General Description	Long"	Long'l Length	Type	-	8	က	4	ស	9	7	8	detection rate
42	Upp Strgr, Face Plate, O/B		4	Æ								4	
42	Upp Strgr, Face Plate, O/B		14	Œ						4		14	0.14
42	Upp Strgr, Face Plate, O/B, Strongback		4	Œ					,	4			0.14
42	Bot Strgr, I/B Rat Hole		•	Œ	_								0.14
42	Long Bhd, Bottom Area							×					0.14
42	Long Bhd, Sqr Bkt		_	LLW									0.14
43+	Bot Strgr, Cutout at Web Fr, I/B		_	Œ					-				0.14
43-	Long Bhd	29	ဗ	LLW					က				0.14
45+	Long Bhd	31	0.75	LLW					0.75				0.14
46+	SS, Erection Butt Pitted	29	2									2	
47+	x	59	2	SLW		8			8			7	0.29
47+	8	30	8	SLW		8			2			2	0.29
47-	8	30	0.5	SLW					0.5				0.14
47	Bott Long	23	_	BKTW		_							0.14
49-	Я	31	_	SLW		-							0.14
49+	88	30	0.5	SLW					0.5				0.14
-09	æ	31	-	SLW		-							0.14
50-	Long Bhd, Grooved Web iwo Toe	30							×				0.14
50-	SS, Grooved Web iwo Toe	59							×				0.14
50-	SS, Grooved Web iwo Toe	30							×				0.14
51+	8	30	-			_							0.14
51/52	B/L's Wasted Welds		9			9							0.14
Total:	22		-	Total	—	7	0	-	11	2	0	5	
Baseline:	22			Hits	•	7	0		11	~	0	5	
				Misses	21	15	22	21	=	20	22	17	

Tank: 3P Note: X = No length given

Note:	X = No length given						Reno	rted	pnoths	Benorted I enaths By Team	Ш		
					_	,	2				ı	2	4. 1. 1. 1. 1. 1. 1.
Frame	General Description	Long'l	Long'l Length Type	Type	-	7	က	4	2	9	7		detection rte
42	Fwd Bhd, Bottom Strngr, SS	13	α	BKTW		0							0.14
42	Fwd Bhd. Bottom Strngr. SS	14	2	BKTW		8							0.14
43/44	Master Butt Weld. Fwd/Aft Toes		1.25	Coat'g Fr						1.25			0.14
4 55-	B/I 15. Bkt Upp Toe	15	2	BKTW								8	
45-46	Small Bkt. Upp Toe	28A	က	BKTW							က		0.14
46+	Bkt Toe iwo Web, SS	30	2	SLW		7							0.14
46-	Vert Bkt Upp Toe to Rider Pl	27	_	BKTW					-				0.14
48+	Web iwo Bkt Toe, SS	30	8	SLW	2	7	8		0.5	1.5		7	0.71
48+	8	31	-	SLW	_								0.14
48+	: 88	29	1.25	SLW						1.25			0.14
48-49	Erection Butt. Coating Cracks, Bottom Lor	ng 16			×			×					0.29
49-	Long Bhd. Insert Plates, Wasted Welds	30			<u> </u>	×							0.14
50/51	Across B/L's Flange Butt Weld Wasted	13	12.5	SLW		×							0.14
51-	Web iwo Bkt Toe. SS	30	0.5	SLW					0.5				0.14
Total:	14			Total	3	9	-	•	က	က	-	7	
False hits				Fise hts									
Baseline: 14	7			Hits	က	9	-	-	က	က	-	7	
				Misses	=	œ	13	13	=	11	13	12	

Tank:	5P					Date of Ex	Experiment:	9/28/99							
Note:	Teams #2 and #6 measured markers	1 #6 measu	red marke	Ī.											
	* = not found									_					
	post-														
	Inspection			•											
	X = No length given	given					-								
	Bold, Italic No Not Certain As to Length	Not Cel	tain As to	Lei	ngth			Reported	Reported Lengths By	y Team		crack	length	hit ra	order
Frame		Longitudi Length	Length		Type	1	2	င	4	ĸ	ဖ	type			0
58	Fwd Bhd, Top 47	47	50	1	BKTW		First 7	First Three Cracks Are Samples	s Are Sam	Selc					0
	Strngr, SS														
28	Fwd Bhd, Top 47 Strngr	47	50		LGW										0
59	8	47	25	Γ	뽔										0
58	Long, Fwd		25		rew	2	MONOSAGE	-	-		-	9	25	0.8	-
	Bhd, Middle Stngr														
28	Long, Fwd	20	75		LGW	ဇ			2		3	9	75	9.0	2
	Bhd, Middle Stngr		- · · · · · · · · · · · · · · · · · · ·												
58	Fwd Bhd, Middle Stngr		09		PLW				4		2.5	9	09	0.3	3
28	Fwd Bhd, Middle Stngr	Nr Ladder 100	100		BKTW	4	4		12		4	9	100	0.7	4
29+	Long Bhd, Middle Stngr	42	50		Œ			2	2		2.5	9	50	9.0	5
28	Fwd Bhd, Lower Stngr	23	75		BKTW		က	င		-		9	75	0.3	9
28	Fwd Bhd, Lower Stngr	21	20	-	ВКТМ			2				9	50	0.2	7
5 9+	Long Bhd, Lower Stngr	35	20	1	FFR?		2	2	7		7	9	50	0.7	&
58	Fwd Bhd	13	12.5		SLW	+					•	1	13	0.2	6
58	Fwd Bhd	14		_	SLW	-	ļ	ļ				-	25	0.5	10
58	Fwd Bhd	20	50		SLW	2	2				2	-	50		11
58	Fwd Bhd	26		_	BKTW	2	2	2	2		2	2	50		12
58	Fwd Bhd		75		BKTW	3	3	ဇ	4		က	2	75	0.8	13
58	Fwd Bhd	29	100		쫎	3	4	4	က	4	4	2	100		14
28	Fwd Bhd		75	٦	쫎	3	4	4			4	2	75	0.7	15

9	7	8	6	0	+	2	8	4	S.	9	7	8	о	0	_	2	3	4	5	9	7	8	6	0	1	2	9	4	5
-	-	3 18	3 19	5 20	3 2	22	7 23		2 25	2 2 6	2 27	2 28		30			7 33	က	3	က	က	က	7 3	40	2 41		4	4	4
0.5	0.8	0.5	0.3	0.5	0.3	0	0	0.5	0.2	0.2	0.2	0.2	0.3	0.5	0.7	0.5	0.	0.5	0.7	0.7	0.7	0.7	0	0				0.5	0.5
75	50	50	50	200	200	75	50	75	7.5	25	25	50	75	100	75	100	50	75	50	75	75	50	100	150	150	150	75	75	100
1	-	-	1	4	4	-	-		1	-	-	1	0	2	1	-	-	ო	3	3	က	9	•	4	4	4	-	-	_
		2	2	7	8		2								3				8	က	က	7	_		9	9			4
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100	100	100												4	- 6		1.5						4						5
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	3	2	2	80	8		2	3					3	4.5	ဗ	4	2	2.5	-	2	1.5	1.5	က						
က	2			9			2	ဗ					2	4		4	2	က	က	3	င	ဇ	-				3		
SLW	VFBW	Œ	₽ĶŢ	bt weld in long	bt weld in	a e	Œ	ସ	TGW	FB weld to BKT	web fr	cutout	BSW	BKTW	SLV	SH.	16	Œ	Œ	Œ	Œ	Œ	BKTW to	B weld to	B weld to	B weld to	tb in fr w?	fb in fr w?	BKTW
		L	F	-	-	-						_	-		⊢	F	<u>-</u>	1	}-	F	<u>-</u>	<u> </u>	<u> -</u>	۱	F	F		⊢	
75	50	50	50	200	200	75	50	75	75	25	25	50	75	100	75	100	50	75	50	75	7.5	50	100	150	150	150	75	75	100
15	29	30	30	25	23	3.0	29	29	29	15	29	29	16	22	29	29	29	27	27	27	27	27	30	21	22	23	28	28	29
Trans Bhd		na Bhd			Long		3 88			b Frame	Long Bhd		ae H	ame	Г			ØKt	SS Bilge Bkt Cutout	SS Bilge Bkt Cutout	SS Bilge Bkt Cutout	SS Bilge Bkt Cutout	Long Bhd	Bottom			Web Frame		88
59					+09	. 08				09	09		6.1	61				61. /62+			61- /62+	61- /62+					62		

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46	47	48	49		51	52	23	7			26	57	58	29		09	61	62	63	64		99	29	89	69	7.0	71	72	73	74	75	92
0.3	0.7	0.3		0.3		0.2	2.0	7		<u>`</u>	0.7	0.8	0.3	0.3		0.7	0.5	0.5	0.3	0	0.3		0	0.7	0.7	0.3	0.5	0.2	0.5	0.5		0.5
										_																						
20		75	100	50	50	75	20	30	3 5	0	75	20	75	20		20	75	75	50	100	50	50	50	75	50	50	75	50	100	100	50	75
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1 0 m		d to	þķt		ığı			밀	1	2	_	ot C	Đị.	ō	1			р 12	٥ .	5				Ð.	to		đ					밁
FT weld to long	web at	tb weld to long		NO NO	fr in stgr		fb/hor	stiff/bhd		long fl	BKT to	BKTW to long fl	fr to lug	BKTW to	nong 1	<u>₩</u>	BKT₹	FR web to	BKTW to web fr	BKTW to web fr	k K	bkt	bkt	FR, long	bktw 1	BKT	- 1	꿆			cutout	bkt weld
-	-	H	⊢						T	-	F	L	F	⊢			F	۲			⊢	L	Ţ	T	T	T	F	-	 -			F
0	D.	ស	100			-				9	2	0	5	0		0	5	2	0	100	0	0	0	5	0	0	ည	0	100	100		_
20	7	75	=	20	20	75	20	35		=	75	20	75	20	+	20	75	75	ις.	-	50	50	20	75	5	20	75	50			20	~
30	30	31	28/29	29	29	30	29	6		ວ	30	21	28	29		29	30	30	20	21	21	22	24	28A	30	14	14	15	28/29	28/29	30	22
	·· <u>·</u>																				П					9						\neg
				Long Bhd	Long Bhd	Long Bhd	Long Bhd	Pag pag	2	roug eug	Long Bhd	Bottom Long Bkt	Web Frame	Web Frame		Long Bhd	Long Bhd	Long Bhd	SS/Bottom	SS/Bottom	SS/Bottom	SS/Bottom	SS/Bottom	Long Bhd	Long Bhd	Web Frame	Web Frame	Web Frame	Bilge Bkt, SS	Bilge Bkt, SS		SS/Bottom
8	8	8	8			٥	2	- -					×	Š	+	9	2	٦	SS	SS	SS	SE	SS					≶	窗	面	88	35
62	62	62	62.	59+	59+	59+	61	C	200	+ 50	63+	63	63	63		63	63	64	64	64	64	64	64	65+	65+	65	65	65	63-	63-	63	64

 $(x,y) = (x,y)^{\frac{1}{2}} (x,y$

											1				-	- 1	-			7	1	
77	78	79	80	81	82	83	84		85	86	0.7	/0	88	68		06	91	26	93	94	92	96
0.5		0.5	0.3	0.4	4.0	0.4	0.4		-	9.0	5	4.	0.2	0.8		_	9.0	0.5	0.8	0.4	0.2	0.2
75 (100	75 (150	100	50 (75 (75	100	7 37	n	50	75 (100	75 (20		75 (100	75 (
2	-	+	9	ღ	2	2	9		ဖ	9	0	٥	9	ဖ		ဖ	9	ις.	9	5	2	2
	4	3	က	ဖ					ო	4				င		4	ဗ	· -	3			
4	5				4	4	4		5.5	-			4	4		٠ ک	4	င	4	4		
			4						-					4		4			4			
2.5	4	4		-		2	က		ဗ	4		က		က		4	င		3	9	4	3
3	2	4		9	4				3	4	,	က				4						
bktw to	BKTW	BKT	FBW to long	bilge stiff cutout	vert stiff to long	plate butt	bktw to	long	bktw to plate.	bktw to	plate, toe	tbw to long	FR, web to fr at	FB w to plate		lug weld to plate at long	fbw to long	plate w near cutout	fbw to	fr plate	bot long fr/bkt	bkt to bot long
L			F	ь.	 - -	F	-		ب	 -		–	-	-			 	F	F	1		
75	100	100	75	150	100	50	75		75	100	ı,	75	50	75		100	75	50	75	75	100	75
15			34	28/29 Ctr	24	15	35		14	20		34	34	Mid Strgr		15	48	5	47	19	21	22
Web Frame	Long Bhd	Long Bhd	Long Bhd, Lower Stngr	8	Aft Bhd	Lower Stngr	Lower	Stngr/Long Bhd	Lower Stnar/Aft	Lower	Stngr/Aft	Lower Stngr/SS	Lower Stngr/SS	Middle Stngr/Web	Frame	Middle Stngr/Aft Bhd	Upper Stngr/SS	Upper Stngr, Partially Covered	Upper Strar	Upper Stngr		
65		65	65	65- /66	99	99	99		99	99		65	65	65		99	65	65- /66	99	99	65	65

97	98	66	100	101	102	103	104	105	106							
9.0	4.0	0	0.3	0.2	0.2	0.2	0.2	0	0							
75	7.5	7.5	50	75	100	100	75	Poss Fr	Poss Fr							
2	1															
	2		2	3						50	2	48	50	0.4898		
					100	100				28	2	26	72	0.26531		
4	4						က			32	1	31	67	0.31633		
										39	0	39	59	0.39796		
-			2	٠	·					69	1	89	30	0.69388		
2								-		52	0	52	46	0.5306	44	54
tank	BKT	LGW	FBW	rgw	Œ	Œ	BKTW to web fr	TB top	TB top	Total	Mis-hit	Hits	Misses	hit rate	Avg Hits	Ava
					 - -	-										
75	75	75	50	75	100	100	75	Poss Fr	Poss Fr							
14	3.4	29	29	30	25	25	20	15	15							
	SS	Long Bhd			Web Frame at L31	Web Frame at L31	SS/Bottom	Trans Bhd	Trans Bhd	106	3	96				
99	65	1 +65 *	* 59+ L	* 59+ F	09.	09.	• 64	59	L 09	Total: 1	Mis-hit: 8	Baselin 98				

		·	
			·
	-		

Appendix C:

Reported Areas, Experiment 2

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					L	_	_	_	_	_		-		
					r = tracture	7		1	$\frac{1}{1}$				1-both crit	
					B = buckling		tollowup						2-only RH crit	
T						T	scraper		+				3-only LP crit	
		1	-		N = not suspect	T	Deported Lengths By		Team					
					- A									
T					wastage	-		1	4					
rame	Tank Frame General Description	Long's Length	gth Type	Followup	P = pitting	1A 2B	30	40 SE	6F 7G	Ħ	Hit Rate	Hit Rate scraper	Critic	
										Kate	scraper		arz	
-	upper strut toe to web fr, marker	upper 125 strut	125mm marker	r yes	Σ					0.00	0.00	0.00	-	
æ	suspect fracture iwo weephole	str 1/B 1/2"-3/4"	3/4"	გ	z	-								
94	BL 16 buckled at attachment to shell 36" from att of	BL16 6"	buckling	Nes ves	6	-				41.0	0 17	000	cumollo) se emes	-
	marker, inboard lap joint 3.25" down from face plate	Ц	3 marker		Σ	_	. 6			0.14	0.17	0.00	2	2
	suspect frac flat bar att. to BL	_		PS,CF	S		2.			0.14	0.17	0.00	2	
_	suspect frac flat bar att. to BL	4		ь	z									
	suspect frac flat bar att. to BL	BL20	7		2									
	marker, 2" near #16 long where web frame meets side		1	r yes	Σ	5.	5			0.29	0.33	0.00	2	
	sideshell buckled at SL#11/12, SL11 buckled up 3"	1			60			*		0.14	0.17	0.00	same as followup	wup
т	BL 16 buckled 6-x1/2" at attachment to SS	9	* buckling		8			*		0.14	0.17	0.00	same as followup	dnw
93F	LL11 frac @ 1st rathole fwd of frame	111			z	_								
93F?		SL 15	coating	_		-								
-	LL10/11 twisting	LL 10	twisting	g yes at SL10		×				0.14	0.17	0.00		
	FB att to BL 19	BL 19	Suspect		z	_								
	FB aft to BL 20	BL20	suspect	8	z	1								
935	FB att to BL 21	BL21	SUSPECT		z	1								
	FB an 10 BL 23	4	7		Z	1	1							
	SI TO DUCKBU UP TO	1	Т			-		*		0.14	0.17	0.00		
	Se husblad burn of a share of to	5 10 10	7		80 (_		***		0.14	0.17	0.0		
36.3	SO DUCKING DIWIT SLY TO ROOVE SLIZ	51.45	Duckling		80	1		*		0.14	0.17	0.00		
-1-	TO all to SE 12 Hange	SL12	SUSPEC		2	1	+							
_	FO an to St. 13 Hange	SL13	SUSDECT		s :	1	×			0.14	0.17	0.00	2	
\neg	for the contract of the forms from a too more year free late with	3L 14	Buspect	5 8	2 2	+						1		
	insert Platy RI 21 extending to RI 1920 moost horized	B. 21	Suspec		Z	+		-				+		
Т	3" frac in Bi 20 to him shell att 41" aft of fr @ wran 4 Bi 20	BI 20	Suspect	٩	2 0	+	+			6	;;		Т	
_	Vo sid, fill/discharge bhd penestrations. Wastage at closest toe to FR91	sest toe to F		١	0	-	-			62.0	2	1.00	1 One same as tollowup	Tollowup
	Vo sid, fill/discharge bhd penestrations, wastage at pi	e cx through	BHDeastac	1	2		+							
	ss buckled in 12"x8"x1/2" aby SL12, 3 it fwd BHD91 SL12 12" buckling	SL12 12*	• bucklir		6		-			0.14	0.17	00.0	mwollof as emea	C. C.
91.5	SL15 to shell conn wasted	SL15	wastage		*	×				0.14	0.17	900	wastane	
9.1	pitting on bulkhead, especially at bottom shel		pittina	L	z								o Aniona	
9.1	BL20, 3" frac. In att weld to bim shell @ web term, ah	BL20 3.			z	_								
=	diag FB to LL17 conn. disattached		fallure	yes	W, 100%		-		*	0.14	0.00	1.00	wastade	
	ladder		ladder		0		_							
91	91 girder to bkhd att.	BL28P 3"	suspect		z		-		l					
9	91 att weld of girder fp to web	BL28P 2.5"	SUSPEC		z		_							
9	9 1 bottom shell buckled up 2'x5'x1 1/2 " up btwn BL29/ BL29P	BL29P	buckling		8			×	 	0.14	0.17	0.00		
91	91 bkhd buckle 8"x12"x1,5" toward att btwn BL29/30P BL29P	BL29P	buckling		8			×		0.14	0.17	000		
91.5	91.5 web att to flange of BL		suspect		z		ļ.,		ľ					
91.5	web att to flange of BL	BL29P 4"	suspect	S2	Z				 					
91.5	91.5 trans fr buckled 21"x17"x1/5" upset ob BL30P	BL30P	buckling	g yes	8				*	0.14	0.17	0.00	same as followup	gn.w
91.5	91.5 web att to flange of BL	BL31P 2"	SUSDEC		2		-		ľ					
								_		_	_		_	

92F	David 35		;	F 000010	2 2	z							-	
36	late her on to test editioner of to Di					•				2000				_
	וומו טמר מוו וס לפון פוווופרופן מוו. וט סב	DLEST	,	Panahari	2 2			<u> </u>						
92F	flat bar att to BL			suspect	2	z		1						
92F	flat bar att to BL	<u>a</u>	1	suspect	2	z								
93	3 marker wf att weld w CVK near cutout at bottom			marker	yes	Σ				0.00	0.00	0.00	2	
ő	93 wf cx to horiz stiffener (2nd from bottom) flange	_	1	Suspect	2	z		+						
6	93 wf cx to horiz stiffener (1st from bottom) flange		•	Suspect	2	z							-	
6	93 upper stillener cx to center line long web	CVKP		suspect	9	z								
93	3 lab seams suspect			suspect	92	z								
93A	stbd outboard lap weld into frame		5.	suspect	suspect	S	×		**	0.14	0.17	0.00	-	
93F	flat bar att to vert stiffener att, to BL	BL25P	. 9	suspect	92	z								
93F	vert stiff to BL att	BL25P	3.5	SUSPECT	æ	z								
93F	flat bar att to BL		2.	Suspect	£	z		-						
93F	flat bar att to BL		2.	Suspect	2	z								
5	One I transcreet from the band flower blickled of blue Bi 4 Bi 200	+-	Ī	or layout	you	ď			,	0 14	0.17	000		
2	93.3 Italisvelse Harrie, wed and harrys overled 2 Olym Di	ריי		Sittle of	90	Z				;		2		
5	5.5 pilling toward bollority	2 10		Bulling	2 2	2 2		† 						
6	או כג נס ווטוול פווופוופן (בווס ויטוון טטווטווון וומיואפ	-		מחסחם	2	2 6		<u> </u>			.,	0	,	
4 .	4 Upper Billiener CK to Certier line forg was	באא		POSDACI	Danana Maria	2			_	<u>*</u>		2000	,	
•	9 4 Iao Bearns Buspect			POPOGO	2 5	2 2								
747	tripping bkt att to wr tp	$\overline{}$	١	SUSPECT	2 !	z :								
94.5	5 trans fr to cyk cx at top of bkt	CVKP		Suspect	2	z								
94.	94.5 bottom shell seam weld btwn 94/95 on bottom suspect	901		suspect	2	z			*					
95	stringer buckled up 1" blwn vert stiff 2 and 3 (from C(HS#3	C(HS#3		buckling	уөв	8			×	0.14	0.17	0.00		
6	95 h.s. #3 (from top) h.s. cx. port long bkhd. 3" fracture HS#3P		3.	Suspect	yes, 4*	Ŀ			4	0.14	0.17	0.00	1 had to	to climb to detect
ō	05 office 1/3 way to			pitting	2	z								
	expansion it holts for cargo line system, 10 & 14" lines	8		polts		0								
6	Super but at to frame	BI 28C		e i e no c t	¥	Z								
100	motion on the frame (a			markor	900	2		۴	7	4 0 57	0.87	0	0	
361	tion fell of to Di	_	T	prienort	S S	Z	1		7					
2	Well Bill all 10 DL	-	,	100000	9	2								
450	Wed all to Harige of DL			Boshor	2 5	2 3	•	-	,	98 0		0	-	
400	market, wild weld I've co	7		inal no	900	2	' 	-				3	-	
¥26	Wed all to Hange of DL		, ;	anapact on a	2 2	2 2								
5	Web all to liaily of DL			Danger of	2 2	2 2								
VEA		פרבאט	,	anahar.	2 2	2								
8		200	1.	Suspect	2 5	2 2		\ 		000	0 22	0	-	
448	marker, wright weld Iwo Co			HIGHE	98.	Σ :		•		4.69	3		+	
94F	vert stiff att to BL	_		suspect	2	z					,	0	,	de de la
ă	95 stringer cx bhd at toe, fracture	HS#33	. 9	SUSPECT	yes	-			*		0.1	0.00	חמם ום	IO CILLIO IO GELECI
	hand rail broken			railing	y98	0								
	bottom shelf pitting throughout			pitting	£	z								
91						0							_	
	pipes pitted exp loints shot					0							_	
	support bkts to framing need replacement					0				***				
16	sideshell cx to bkhd suspect	SL13		suspect	22	z	_							
-6	Bkt iwo SSL14	SL14		suspect	S	s		_	*	0.29	0.33	0.00	0 000	one same as followup
9	sideshell cx to bkhd suspect	SL 14		suspect	S	S	×		<u> </u>	0.14	0.17	0.00	1	
916	+	SI 14	. 8	buckling	Ves	8		×	`* 	٥	0.33	0.00	620	same as followup
=	-	\$1.15		Suspect	S	S	×				0.17	0.00	-	
6	eldoshall ov to higher enement	91		RIBDACT	ď	cr.	×			<u> </u>	0.33	0.00	1 one	one same as followup
5	hit at to hind for from ton of hit in eide	R 18		Suspect	S.	S		 *	ľ	! 	0.17	0.00	2	
5	marker 14" from top of circler ib side. 3"	BL20		marker	Nes .	Σ		3		0.14	0.17	0.00	0	
4	_	BI 20		frans.	enement	ď	*]	0 14	0.17	000	٥	
2 4	_	81.20		ellener!	Scale	2			Ī	<u>:</u>		3	-	
9	_	B 20		RUSDACT	S	ď				0.14	0.17	0.00	2 sam	same as followup
-	$\overline{}$	81.23		wastade	Sev.	3				l	0.00	1.00		wastage
5	at weld of his to bid ov	11.15		trenari	g v	2								
	uo pilo oi nio io pion iin	3			2	2	_				_		-	_

1. 1. 1. 1. 1. 1. 1. 1.	ID IWO IT, Droken Weld on FB Still		broken we	not found	0					-		
11.15 Subspect S	aft of fr 92 Iwo cutou	3L20	suspect	S	S		*	0.14	17	4		
1. 1. 1. 1. 1. 1. 1. 1.		L16	Suspect	s g	s z	×	×	0.29	33	+	T	
Strict S		51.14	Suspect	2 5	2 0			;	+	3	- 11-7	
1.1 1.1		21.14	DOCKING	Sey.	n z		* 	<u>.</u>	╀	0.00	Same as followup	
Bit Suspect N.S. N. N. N. N. N. N.		31.16	SUSDBCI	S	S	<u>×</u>		0.14	1	+		
BL2 Suspect S S S N N N N N N N		31.17	suspect	SZ	z				\vdash	╀		
BL21 Suspect School Sc		3L21	suspect	s	ó	×		0.14	Н	Н		
St.15 Suppler St. 5 St. 7 X X X X X X X X X		3121	Suspect	S	σz		*	0.14	+	+	same	Ī
Bit Suspect S S N N O 14 O 17 O 000 2 Bit Suspect S S N N O 14 O 17 O 000 2 Bit Suspect S S N N O 14 O 17 O 000 2 Bit Suspect S N N N N N N N N O 14 O 17 O 000 2 Bit S Suspect S N N N N N N N N N		21.15	anapact a	SCAR	,	,		000	┿	\perp		
Bit 10 Suspect Science Scien		31 16	Suspect	c,				0 14	╁	+		
1911 1915		3L17	SUSDECT	S	S	×		0.14	╁	\perp		
BL18 Suspect S		31.18	suspect	scale	z				┼-	-		
BL23 Suspect NS		31.18	suspect	S				0.14	0.17	H		
Signature		3123	suspect	SV	Z					L		
Sign		9125	marker	٤	0							
Sight Duckled Duckled B		SLB	buckled	buckled	8		*	0.14	0.00	1.00		
Style	nes	SLB	buckled	packled	8		*	0.14	0.00	1.00		
Strict Duckled NS		SL9	buckled	pelyong	8		*	0.14	0.00	4.00 4.00		
Still Buckled Buckle		SL 10	buckled	buckled	8	×	*	0.29	0.17	1.00		
Surgiciary Marker New	long buckled up 4" biwn frames	SL11	buckled	packled	В		*	0.14		1.00		
Little	shell plate weld above riveted lap		suspect	not found	0							
Strict	marker, wf to bottom strut OB	oottom			:				-	ļ		
11.14	Т	Strbt	шагкөг	уөв	Σ		-	0.00	+	+		
L114 Buspect NS		EL13	wastage	2	z							
Little	att, weld cx long to frame	L14	suspect	22	z	-						
Silic		L15	suspect	æ	z							
Signo		SL10	buckling	yes	8	×		0.14	\vdash	0.00		
SLI5 Supplect NS		SL 10	buckling	yes	8	×		0.14	Н	0.00		
SL15 Support NS		6T8	buckling	96Å	0							
B118 Suspect AS N N N N N N N N N		SL15	suspect	SZ.	z							
Second Biliary Biliary		31.18	suspect	g	z							
Name BL23 BL23 BL23 BL24 BL25 Buspect S S X X D.14 D.17 D.00 2 D.14 D.17 D.00 D.14 D.17 D.15 D.	I	3L22	suspect	scale	z							
BL20 Suspect NS N	Ī	3123	Buspect	S	S	×		0.14	\dashv	4		
Strict		31.20	SUSPECT	2	z				+	4		
Control Cont		91.20	тагкөг	198	Σ (×		0.14	+	+		
Litis Suspect S S X X O.29 O.33 O.00 2 One same		1 13	Danana Panana	0	0		x ,	-	+	+		
SL14		114	allenart		, ,	-	ľ	200	╀	4	8	
SL16		St 14			0	-	**		╀	╀	5	
SL16		SL15			0							
Applicating Co Co Co Co Co Co Co C		SL16			0							
All the line insert places Part of the bright blue insert places Part of the bri	seams lb/ob				0							
Applicating SL15 Buckling N N N N N N N N N	lap seams suspect				0							
Searing SL15 Duckling Duc	shell rivets worn				0							
Secring SL15 Duckling Duc	frame to stiffeners wasted				0							
Second S	e brackets at SL15/16 twisting/tearing	_	buckling		z							
shell lwo insert pl BL20 20° suspect GF N x x x 0.43 0.50 0.00 one same 0 lightning hole BL20 1/2° buckling yes B x x x 0.50 0.00 2 BL18 marker yes M 2° x x 2° 0.57 0.67 0.00 2 BL22 suspect PS,CF S x x x 1.00 2 SL15 suspect OF N x x x x x x		4	suspect		z							
o lightning hole BL20 1/2" buckling yes B x x x 0.43 0.50 0.00 cone same BL18 marker yes M 2" x 2" 0.57 0.67 0.00 2 BL22 suspect PS,CF S x x x 0.29 0.17 1.00 2 SL15 suspect OF N x x x x 1.00 2		4	Suspect		z				-			
BL18 marker yes M 2" x x 2" 0.57 0.07 0.00 BL22 suspect PS CF S x x x 0.29 0.17 1.00 SL16 suspect OF N x x 0.29 0.17 1.00	de btwn BL20/21 1/2" upset two lightning hole	4	puckling		B	×	×	\dashv	+	4	one same	
BL22 suspect PS_CF S x x 0.29 0.17 1.00 SL15 suspect CF N	/o for BL #18	BL 18	marker	уөв	Σ		<u>ا</u> رہ	-+	\dashv	4		
SC15 suspect C-		BL22	suspect	PS,CF		×	*		+	+		
	SL15 lap seam on wr	SL15	suspect	5	2			1				

22 6.96 Eugener of the Residue of the	X X X 0.57 0.50 1.00 1.00	2 Core same as followup 2 same as followup 2 same as followup 0 o same as followup 0 o same as followup 2 same as followup 3 same as followup 3 same as followup 3 cacesible 2 accesible 3 came as followup 1 one same as followup 1 one same as followup
No. 812301, 17 8120 8185pect No. 8 N	x 4 1 0.37 0.30 x 4 1 0.71 0.83 x 6 0.57 0.50 x 0.20 0.25 x 0.20 0.20 x 0.20 0.20 x 0.20 0.25 x 0.20 0.25 x 0.20 0.25 x 0.20 0.25 x 0.20 0.25 x 0.20 0.25 x 0.20 0.20 x 0.20 0.25 x 0.20 0.25 x 0.20 0.25 x 0.20 0.25 x 0.20 0.20 x 0.20 0.20 x 0.20 0.20 x 0.20 0.20 x 0.20 0.20 x 0.20 0.25 x 0.20 0.20 x 0.20 0.20 x 0.20 0.20 x 0.20 0.20 x 0.20 0.20 x 0.20 0.25 x 0.20 0.25	
March BIL20 Wastage CF N N	*	
The prosoble marker Bilis Bilispect CF N N Silis Bilispect CF N N Silis Bilispect CF N N Silis Bilispect CF N N N Silis Silis Bilispect CF N N N Silis S	* * 4* 0.71 0.83 * * 4* 0.71 0.83 * * 0.14 0.17 * * 6* 0.14 0.00 * * 0.14 0.00 * 0.14 0.17 * 0.14 0.15 * 0.15 0.15	
A	* * 4* 0.71 0.83 * * 4* 0.71 0.83 * 0.14 0.17 * 0.14 0.00 * 0.15 0.00 * 0.00 0.00 * 0.00 0.00 * 0.00 0.25 * 0.20 0.25 * 0.20 0.25 * 0.20 0.25 * 0.20 0.25 * 0.20 0.25 * 0.20 0.25 * 0.20 0.25 * 0.20 0.25 * 0.20 0.25 * 0.20 0.25 * 0.20 0.25	
15		
SLI5	x 0.20 0.25 x 0.20 0.25	
SL15, 3 1/2" SL15	*	
SL14 Suspect PS, CF S X X	x x 6 0.14 0.17 x x 6 0.14 0.00 0.05 0.14 0.00 0.00 0.00 0.00 0.00 0.00 0.25 0.20 0.25	
SL15 Suspect PS_CF S	* * * 6 * 0.14 0.17 * * * 6 * 0.14 0.00 * * * 6 * 0.14 0.00 * 0.14 0.00 * 0.14 0.00 * 0.14 0.00 * 0.10 0.00 * 0.20 0.25 * 0.20 0.25 * 0.20 0.25 * 0.20 0.25 * 0.20 0.25 * 0.20 0.25 * 0.20 0.25 * 0.20 0.25 * 0.20 0.25 * 0.20 0.25	
SL15 Suppect PS,CF S X X	W W W W W W W W W W	
BL22 Bu26 PS, CF S X X	X Q.57 Q.50 Q.5	
Public at turn of girde BL20	x 6 0.14 0.00 0.00 0.00 0.00 0.25 0.20 0.20 0.20 0.20	
Died side, marker Died	x 0.20 0.25 x 0.20 0.20 x 0.20 0.20 x 0.20 0.20 x 0.20 0.20 x 0.20 0.25 x 0.20 0.25	
Indication CVK	0.00 0.00 0.00 0.00 0.00 0.00 0.20 0.2	
BL26	0.00 0.00 0.00 0.20 0.20 0.25 0.20 0.25 0.20 0.25 0.40 0.50 0.20 0.25 0.40 0.50 0.20 0.25 0.20 0.25 0.20 0.25 0.20 0.25 0.20 0.25 0.20 0.25 0.20 0.25 0.20 0.25	
Marker Week W	x 0.20 0.25 x 0.20 0.25 0.20 0.25 0.20 0.25 0.20 0.25 0.20 0.25 0.20 0.25 0.20 0.25 0.20 0.25 0.20 0.25 0.20 0.25	
CVK	N 0.20 0.20 0.20 0.20 0.20 0.20 0.20 0.20	
BL28P 0.6" suspect S S mark BL28P suspect S S X BL28P suspect S S X BL28P 4" suspect NS N X BL28P 4" suspect S S S BL28P 4" suspect S S S BL28P 5" marker Yes N X BL28P 5" marker S S S BL28P 5" marker S S S BL28P 4" suspect S S X BL28C BL28 suspect S X BL28C BL28C BL28C S X BL28C BL28C BL	8 0.20	
CVK 1 Suspect S S N BL26P 4 Suspect S S X BL26P 4 Suspect S S X BL26P 4 Suspect S S X BL26P 4 Suspect S N X BL26P 5 Marker Yea N X BL26P 5 Marker Yea N X BL26P 5 Marker Yea N X BL26P 5 Marker S S S It CVK 1 Suspect S S S It BL26P 4 Suspect S S S It CVK CVK Marker Yes? O It Detwn BL26 at co BL26 S S S It Marker CVK Marker Yes? O It Detwn BL26 at co B S S X It But But But S S X It But But S S X It But	0.20 0.20 0.20 0.20 0.20 0.20 0.20 0.20	
BL28P Suspect S S X BL28P Suspect S S X BL28P 4* Suspect S S X BL28P 4* Suspect S S N BL28P 4* Suspect NS N X BL28P 4* Suspect NS N X BL28P 4* Suspect S S S CVK 1.5* Suspect S S S CVK 1.5* Suspect S S S CVK 1.5* Suspect S S S In	6 0.40 0.20 0.40 0.20 0.20 0.20 0.20	
BL28P Suspect S X X BL26P 4" Suspect S S X BL26P 4" Suspect S S X BL26P 4" Suspect Coaling N BL28P 4" Suspect NS N BL28P 6" marker Yes, fracture F BL28P 6" marker Gore O BL28P 6" marker S S It CVK 1" Suspect S S X It	0.20 0.40 0.20 0.20 0.20 0.20 0.20	
BL28P	0.20 0.40 0.20 0.20 0.20 0.20	
BL26	6 - 0.40 0.20 0.20 0.20 0.20	
BL26P 4' suspect coaling N BL26P 4' suspect Coaling N BL26P 4' suspect NS N BL26P 4' suspect NS N BL26P 5' marker yes N BL26P 5' marker yes S BL26P 5' marker S S It CVK 1' suspect S S S S It CVK 1' suspect S S S S It CVK 1' suspect S S S S S It CVK 1' suspect S S S S S S It Meld to CVK 1' suspect S S S S S S It weld to CVK 1' marker Nes? O O S S S S S It weld to CVK 1' marker Nes? S S S S S S S S S S S S S S S S S S S	6 - 0.40 0.20 0.20 0.20 0.20	
BL26P 4* Suspect Coating O BL26P 4* Suspect NS N N N N N N N N N	6 0.40 0.20 0.20 x 0.20 x 0.20	
BL26P 4* Suspect NS N N	6 0.40 0.20 0.20 0.20 0.20	
BL26 6" marker Ves N X BL26P 5" marker Se N X BL26P 5" marker Se Se N X BL26P 5" marker Se Se Se Se Se Se Se	6 - 0.40 0.20 0.20 x 0.20 x 0.20	
BL26 6" marker yes M x tank	0.40 0.20 0.20 0.20 0.20 0.20	
BL26P 4' suspect yes, fracture F BL26P 5' marker gone O O O O O O O O O	0.20 x 0.20 x 0.20	
CVK 1° suspect S S	x 0.20 x 0.20 x 0.20	
CVK 1.5° suspect S S	x 0.20 x 0.20 x 0.20	
CVK 1° suspect S S	x 0.20 x 0.20 x 0.40	
CVK 1.5* euspect S S S S S S S S S S S S S S S S S S S	x 0.20	
BL26 4* S S S S S S S S S S S S S S S S S S	x 0.40	
BL27 2* suspect S S	x 0.40	
CVK 1 Suspect NS N		910
Marcon CVK Suppect S S S S S S S S S		920
New 90		920
Pung bhr 8	X X	20
B129P 4* suspect S S S S S S S S S S	× × 0.60	
4 • suspect NG N 2 • suspect S S 3 • suspect S S 3 • suspect S S 6 • buckling ? 0 60 • buckling yes B 60 • suspect S S	x 0.20 0.25	-
2. suspect S S S S S S S S S S S S S S S S S S S		
2. suspect S S S 3. auspect S S S 3. auspect S S S S S S S S S S S S S S S S S S S		
3	000 008	3 one same as followup
3	ľ	T
### ### ### ### #### #################	N.20	Sallie as lollowup
6. buckling ? 0 6. buckling yes B 6. suspect S 8. suspect	x 0.20 0.25	
60° buckling yes B C S S S S S S S S S S S S S S S S S S		
60° buckling yes B S S S S S S S S S S S S S S S S S S		
60* buckling yes B s s s s s suspect S s s suspect S s s suspect N N N		
60° buckling yes B s s s suspect S S S suspect S S S S S S S S S S S S S S S S S S S	188	
Suspect S S S Suspect S S S	4	
BI.28S suspect S	0.20 0.25	7
RI 28	0.20 0.25	~
S toedsile	0.20 0.25	0
1000000	0.20 0.25	0
o spendence of	╄	
8USpect S	03:0	o o o o o o o o o o o o o o o o o o o
yes	+	маокано
suspect undercut		
S Bi 31S 2" marker ves	2. 0.20 0.25	-
Bi 97S 4 suspect		
nondene		<u> </u>

 $(x_1, \dots, x_n) = (x_1, \dots, x_n) + (x_1, \dots, x_n$

SSS	90F	Marker S side of cl face plate weld	Š	9.	marker	Nes	Σ	_	-	0	0.00	0.00	F		
SCS	90	$\overline{}$			15	yes, fracture	T.	×		•	H	0.50	-	accessible	
SCS.	90			8.8	suspect	S	S	×	×	× 0.	0.60 0.	0.75	-	one same as followup	
SS	90F	_	BL26	3.8	suspect	S	S			×		0.25	0		
SSS	9	buildge in bkhd plating to stringer 6' above bot blwn E BL30S	BL30S				0	+			+				
SCS	91	om Iwo bhd 90	š	<u> </u>	Suspect	2	z		4		1		4		
တ္လ	91	side lab on wi iwo SL14-15	SL 14	1	suspect	\$2	z				+		-		
SS SS	6	side lab on w/ Iwo SL14-15	SL 14	-	suspect	<u>ي</u> د	2 2		<u> </u>		1	1	+		
1	0.00	DIZU DUIT WHIT WESTIFING O MUNTO DECK	מונים	T	Wastage	2	2]; 		.	+	+	+		
3 %	Š	with hickled aft 1" aby lichtning hole blum BI 21-22	BI 21	9	marker	yes	5 a	9	x >	ا د	0.57	0.50 1.00	2		
SS	06	BL15 to w/90 and bkt at lower rat hole ob	81.15		Suspect	3	z		-	۶ 	╄-	┼			
SS	89F	BL22 upper bkt cx to underside of flance	BL22	-	Suspect	2	z		 			-			
SS	89	SL15 flange conn to wf89	SL15		suspect	2	z						-		
SZ	68	ob lap in w/90 lwo SL14/15	SL14	93	suspect	22	z			 					
25	89A	marker, c/o blw bottom HS bkt iwo SL14?	SL14				ž						-		
28	89A	1" marker BL18 att to fr	BL18		marker	yes	2	1.	×	× 0	0.57 0.	0.50 1.00	2		
28	88	buckled above lightning hole btwn bi23	BL23	נ	buckling	yes	8				-	H	-	same as followup	
28	88.5	clean ib side btwen bi21/22	BL21	40	suspect	SS	z								
Н	89	buckled iwo lightening hole BL21/22	BL21	4	buckling	yes	В		*	0	0.14 0.	0.17 0.00			
SS	88	lap w/88 iwo SL14/15	SL14	3	suspect	scale	z								
25	88	BL15 cx to fp 88	BL15	W	suspect	£	z								
2S	88	lap wf ib side above bi22/23	BL22	-	suspect	S	S	×		o	0.14 0.	0.17 0.00	-		
SS.	88	s113 buckled up 1" btwn fr 88-87	SL13	-	buckling	yes	В				-		_		
28	87	at SSL13	SL 13		тагкег	yes/peeling	×	. 4	×	×	_	\dashv	4		
SZ	87	_1	_	1/2.	suspect	S	S		***	×	0.14 0.	0.17 0.00	4		
SS	87	1st ib lbh above botton	-	1 1/2"	suspects,	not detrimen	Ä.		×	ا• ا	-	-	-	accessble, not critical	
2S	87	BL20 at upper bkt cx to wf87	BL20	1	suspect	S	×	×		ò	0.29 0.	\dashv	-		
45	837	keelson fwd cs to stringer faceplate	BL20		Suspect	S	×			9	0.14 0.	0.17 0.00	٥		
\$;	83	_	SL 10	†	-	yes, broken	× 0,		1	o	0.14	0.17 0.00	_	broken stringer	
4 6	82F	_	St. 14	1	Suspect	2	z		1		1		4		
÷ ć	821	_	 	<u> </u>	Nobecta	suspect NS (repair weld	z		-		+	+	1	1	
ţ :	20	十		ğ	Oroken we	yes			×) 	0.14	0.00		Droken Weld	
+	900	DI 45 or to mob food throton moldon	4	+	Dana Dana	No locale)	Ť	 -	T	°	+	+	+		
÷ 0	20	being strings for out to the sifferer underside at the	2 2 2	7	SUSPECI	n	× ;	×	×	- - -	0.00	0.83 0.00	2 9		
9	ACA ACA	con on wet frame to show less of	5	-	euenert	2 2	T		-	خ اح	+	╁	+		
4	815	+			Suspect	S	S	*	-	6	0.14	0.17	6		
4	81			3	suspect	တ	×	×	×	0	Ļ	⊢	1		
4	81	outbd lap seam		<u> </u>	suspect	92	z			 	┞	-			
4	81	face	81.15		suspect	S	×	×		9	0.29 0.	0.33 0.00	0		
4	80.5	SL8 area near center of bay buckled	SLB	נג	buckling	yes	В		×	0	0.14 0.	-			
4	80	\neg		3	suspect	S	S	×	×	0	0.29 0.	Н	-		
-	80	コ		w	suspect	2	z								
4	80	Inbd c/o on web fr fp above lap seam		w	suspect	တ	s	×	×	0	0.29 0.	0.33 0.00	2		
4	80A	SL15 fr cx to se blwn rvts	SL15	S)	suspect	£	z								
4 P	79.5	SL8 area near center of bay buckled	SLB	<u></u>	buckiing	998	60		×	•	0.14 0.	0.17 0.00	_		
4p	79	long, keelson at bkhd 79 frac 1st vert fb to flange pit	BL20	3	suspect	S	×			0		-	0		
4	79	long, keelson at 5khd 79 1st face plat butt it undersidi	BL20	. w	suspect	52	z								
4	79	BL20 cx to 1st stringer at fwd bhd	BL20	1	suspect	-	0				+	_			
48	83	\neg	-	7	suspect	ь	z					-	-		
45	83	btm string cx to ss lap joint		1	suspect	2	z				-		-		
φ ç	83	SL10 cx to he #2	St 10	7	suspect	2	z			1	+	1			
2 6	20	DIM 2/3 OF 18D WOLD IWO DI 22/23	DL22		BUSDBCT	2	z		# 		+	+			
2 9	728	LLID DKI att 10 WT	113	7	SUSPECT	2 5	2 2		# 		+		+		
1	170	girder L-20 intersect with write	07.0	+	enspect	5 8	2 2	+			+	 	\downarrow		
?	်		270		POPDECI	5	1				-		4		

	270	suspect		z	1	<u> </u>	Ī	+	$\frac{1}{1}$	+	
1.22	BL22	Suspect		z		+		+			
LL 14 att to wf Iwo long bhd	LL14	suspect	ŀ	z			1				
LL 15 att to wf Iwo long bhd	LL 15	Buspec		S	×	×		0.29	0.33	0.00	2
LL 16 att to wf Iwo long bhd	1116	suspect	e e	z		+	1				
	11.17	Buspect		z		٦,				+	
7	BL22	marker		≨ (. [* *	+	+	+	1
	BL 20	suspect		S		×	×	0.43	00.00	00.0	one same as lollowup
ven W/L14) under	LL14	suspect		z		+	Ī	4-	╀	╀	
WF (and SL17)	SL 14	suspect	0	S	×	+	l	0.14	/:0	0.00	2
7	LL22	SUSPECT		z		+				1	
lap lwo SL14/15 (and abov top of lap/below c/o)		┪		z		T			1	4	
	BL22 3*		İ	S	×	×	1	4	+	0.00	2
	SL15	suspect	ct CF/PS	S	×			4	17	4	2
	81.22	Suspect		S	×	×		0.29	0.33	0.00	2
SS lun Sits (lun rhats)	St 15	SUSDBC	Ь	z					-	_	
ahy hid		SUSDAC		z			ľ		_		
	61 13	Suspect	5	z			[
	** 10	Fieren		z			l				-
	ŀ	_		2 2	1	 	ľ				
	7	_		z			l	+			
1 1/2" frac in web att. to LL15 flange@c/o	St.15 1 1/2"	1/2" suspect		z		7	1			+	
	BL 19	marker	er yes	Σ		2.2	*	0.57	20	4	
b bk()	BL20 1 1	1/2" suspect	ct CF/PS	S	×	×	*	0.57	0.67	0.00	2 one same as followup
	L	_	90 CF	z				***			
ton on airder	00	SUSPEC		z				3000			
_	200	on of other		z			l				
LZU, 181 Vert Billi from noc, Billi to girder cx wasteu	21.00	Wabia	2 2	2		-			-	-	
BL23 near FH/9, ver. stiff attached to ond weld waste DL23	575	Masiaye		2 0	T			;;	╀	5	
딞	- 1	1		9		×		+	+	+	
SSL#15, 1" frac in heel of tripping bracket (marker?)	St.15 1	* suspect	ct yes	S	7	- ×		+	<u> </u>	0.00	2
SSL#14, 3" frac. In FB att weld	SL14 3"	* suspect	ct wastage	*		×		0.29	0.33	8	wastage
top of lap lwo BL22-23 lb	81.22	suspect	업	z						1	
se cx to web ob	SL14	suspect	ct no	z					1		
qo	SL14	suspect	ر 10	z							
	SL11 3 1	1/2" suspect	ct yes	s		×		0.14	0.17	4	2
abla do no Hanor	=	7		4.B		×		0.14	0.17	0.00	broken weld
Ī	SI 14			2							
	L	T		z							
do etoria	77 10	to de la constante	2 2	z							
†	Ļ	2 - C		2		_				-	
SLI4 Hange CA 10 Web	ļ	T		Z					-		
Ŧ		T	2 2	Z		-				-	
BLZ3 hear If, Vert, Stiff, all to ond well wasted up to	01.63	Maplan	l	2 2		<u> </u>					
	BL22	BUSDBCI		2 :		+					
angle (vert.) bkt support csx to fr laceplate		Buspect	130	z	7					+	
long'l attachment	SL13	suspect		2	Ţ	+					
	SL 13	broken we		z				+			
SL14 broken weld to SL	SL14	broken we		Z				1	+	+	
CVK Iwo#3 (frmbtm) hor, stifn, frac. Iwo att to bkhd	CVK	suspect		z					+	1	
-	BL29	buckling		8	×			0.14	0.17	0.00	
th stiffener two cvk extension from fr79 to fr78	CVK	SUSPEC		z		-		***	-		
	Š	SUSPECT		S	×	×	-	0.29	0.33	0.00	0
top of Ib lao seam at fr78		Suspect									
ast @18" from bottom	BL 31	buckling		z				888			
motto	Š	SUSDECT	S	s		×		0.14	0.17	0.00	3
lan of w/ hatwaan BI 25/28	81.25	suspect		z				***		_	
lab loint outboard at too		Suspect	NS NS	z							
6/28	10 to	RUSDACT		z							
								-	-		

																														same as tollowup	OIN SAILE AS IOIOWUD		ame as followup										9					
														\downarrow															stag	w, one s	OI B SAIL		w, one same			-							accessible					
-		-		4	-	-	+	4	00	+		+	+	+	2	-	00 2	\dashv		+	2 0			00	+		_		-	+		-	\sqcup		8	╀				1	+	-	0	\vdash				
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					-	4 0.17	+	o	9 0.33			4	4	+	4 0.17		3 0.33	4 0.17			9 0.33		-	0	+	L			0	4	4 0.00	0	0	-	64	<u> </u>			-	_	+		3 0.33				1	
						0.14		0.14	0.29				<u>*</u>	0.1	0.14		0.43	0.14		;	0.29			0 14	- -				0.29	0.29	2 2			-	-				_	+	1.	-	0.43				+	
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										7	1									1	1		+								-			1	1				data		1						1	
SZ.	۲	2	2	~	٠	S	2	S	S	2	2	و	0	တ	S S	2	s	S	22	٠,	מ	-	2 2	2 0	2	2	8	b	100% wastage	100% Wastag	0	S	100% wastag	₽ P	00	Yes,	0	₽ĊF	-	2	2	z	/es (4" fra	NCF	NCF	z	₹ P	
suspect	suspect	Suspect	suspect	suspect	suspect	suspect	suspect	suspect	suspect	suspect	Suspect	suspect	Suspect	Suspect	Suspect	Suspect	suspect	suspect	Suspect	washed or	SUSPECT	Suspect	suspect	Suspect	SUSPECT	suspect	suspect	suspect			Suspect	Suspect		suspect	٠.	Suspect	Suspect	Buspect	_	suspect	Suspect	SUSPECT	-			suspect	suspect	
3				8				<u></u>		-	-		-						٦	wa			,											ŭ				8	Ť				4 1/2		J	8	1	
BL25	BL24	ÇK	81.31	BL25	BL28	š	Š	Š	81.28	BL30	BL 29	BL26	0770	BL25	30.10	חרבה	BL26	BL26	BL25	BL 28	8 6	BL30	2/2	7 7	Stro4	Š	e-Igi bhd	e-igi bhd	s-lgi bhd	Dud Bi-d	000 100-0	•	٩	충	87.8	0710		BL25	BL27	BL28	6	8128	+	-	BL26	BL28	BL25	
25	24						rt bkt			30	59				8									other side - ethner plate ov to fuel bb70 lun tet vert	B INO ISI VEIL	H str4 stbd side to two CVK @FR78/79 at top of horoz bkt cx					port 1 frac in web Office termination at the aft of hhd7	@tr78						at angle	at angle			, 4. 00 c/o1	BL28 12" aft of frame, girder to frac@butt weld ovb	o fp				
frac. web frame att. to flange of BL25	2" frac, web frame att. to flange of BL24				BL28-frac in lap seam @ lower rat hole	CVK lap joint at top (1st lap from BHD)	CVK 1st horizontal under piping support bkt			3" frac. web frame att. to flange of BL30	3" frac, web frame att. to flange of BL29	98	62	25/26	2" frac, lap joint@ c/olor ibhd-bim shell cx		đ	bkt on BL26 at cx to face plate on web		ĮĮ.				o fued this	DM 0	79 at top				por 3 rac in art. Weld to por 1-ond (pir/s	Ination at	H str2 port 5" frac. In att. weld to port L-bhd @fr78		1 bhd	d bhd	TING CX		BL25 penetration to web fr cx suspect at angle	BL27 penetration to web fr cx suspect at angle		1	girder L-28 tripping bkt att to frame tp. 4"	to frac@	BL28 att weld to fr @ wrap weld on o/b fp				
att. to fla	aff. to flar	5 Seam	CVK	3/26	m @ lowe	(18t lap i	under pip	C K		aff. to fla	aff. to Ila	web att. to long flange at BL26	Web all, to long liange at DLZ5	bottom of lap near c/o at BL25/26	Votor 10h	E	BL26 cx, seam in web frame fp	face pla	bott of lap near c/o BL25/26	BL28 to seam weld washed out	BL30/31	31	upiBei	nlate ov	Didie CA	K @FR78	x at toe	phd n	at toe	d 01 Die#	H atro port 1" frac in web @fn termination	weld to p	toe 2*	CVK lap seam (vert) near fwd bhd	girder L-28 fap seam near fwd bhd	too of o/b lab loint (in web)	(E	web fr c.	web fr c	eb fr fp	(III Web)	okt att ti	ne, girdei	Ø wrap v	3/25		top/btm)	
b frame	b frame	, top of la	ear BL31/	IWN BL2	n lap sea	in at top	orizontal	al lap it o	Q	op Irame	o Irame	long flar	BII BUOI	ap near	oint@ c	'e lan 6e8	eam in w	8 at cx tc	near c/c	am weld	Weld IWO	W0 BL30/	or behal	etringer	DE LINE	b Iwo CV	phd gno	oe, frac.	long bhd	c in air.	in weh	c. In att.	the cx at	Bam (vert	lap sear	lan ioint	nt (top/bt	itration to	tration to	9 att to w	IND ON	Bridging	aft of fran	eld to fr	IWO BL2	o web fr	125/26	
2" frac. we	frac, we	CVK at FR, top of lap seam	lap weld near BL31/CVK	lap weld blwn BL25/28	L28-frac	VK lap lo	VK 1st h	CVK vertical lap it on CVK	BL28 at top	frac. we	frac. w	veb att, tc	190 all. 10	ottom of	2" frac, lap joint	fo c/o above lan seam	L28 cx, 8	kt on BL2	ott of lap	128 fp st	2" frac in weld Iwo BL30/31	lap weld Iwo BL30/31	CVV las sees but o	ethd elde - ethnos	cx to lbi	tbd side	stbd side long bhd cx at toe	H str3 1-bhd iwo toe, frac. in bhd	H str2 stbd cx to long bhd at toe	81 S 10	ort 1" fra	or 5" fra	port strg/lbhd cx at toe 2"	VK lap s	Irder L-28	ton of o/b lan joint (in web)	/b lap joint (top/btm)	125 pens	127 pent	girder L-28 att to web fr fp	top of 6/0 lap joint (in web	inder L-2	1,28 12"	128 att w	top of lap Iwo BL28/25	girder att to web fr	lap Iwo BL25/26 (top/btm)	
77F 2	П	77 0	П	76A Is			ヿ			_	_	7	T	_	77F 2	\top		_	\neg	_	_	т	18,	-	Hatra	H Str4 8	H str3 s	H str3	H Str2	בון פוניו		H str2 p	H str3 p	$\neg \tau$	\top	76F	_		_	_	_	747	1	$\overline{}$			73A I	
50P	5CP	S S	55 P	5CP	S S	SP	Š.	ဦ	SS	င္သ	SS	တ္ထ ရ	3	SCS	တ္တင်	3 53	SCS	5CS	5C8	SCS	3	SSS	3 8	-		+-	_	SCS	-+		ខ្លួ	-	-	ဋ္ဌ	8 8	S S	å	දී	စ္မ	ဦ	3 8	နှင့်	දු	8	9CP	ဦ	90 6	

11/25/98

SO9	75A	75A lap of fr Iwo BL25/26	BL25	suspect	Z	z	-					H		
ecs	73A	73A BL26 bkt cx to web fr fp	BL26	suspect	NFCF	z								
809	73F	73F top of lap joint two BL26	BL26	suspect	N-CF	Z								
SCS	73F	73F top of lap joint two BL30/31	BL30	suspect	N-CF	z								
8C8	73F	web fr to long cx (flg) BL25	BL25	suspect	N-CF	z								
8C8	73F	73F web fr to long cx (flg) BL26	BL26	suspect	z	z								
SCS 8CS	73F	web fr to long cx (flg) BL27	BL27	suspect	NCF	z								
SCS BCS	7.3	73 Ip cx to tripping bkt (BL26)	BL26	SUSPECT		Z								
SS	73F	73F Lbhd seam weld suspect		suspect	S.	z								
တ္ထ	74A	74A Itp frac (6"@ tb cx lwo BL26)	BL26	SUSPECT	suspectives, 1 1/2" frai	F	×	* *	×	1.00	1.00	1.00	1 accessible	
ပ္သ	74A	74A ob lap joint at top, 3" @ c/o, BL25/26	81.26	suspect	yes,4" frac	T.	×	×	×	98.0	0.83	1.00	1 accessible	
SO9	74F	74F BL28 att to web fr fp	81.28	suspect	NCF	z								
SOB	75F/A	6CS 75F/A lap iwo BL30/31	81.30	Suspect	z	z								
SCS	75A	75A web fr to weld two BL28/27	BL26	suspect	NCF	z								
SCS	7.5	75 web fr c/o lwo BL26	BL26	suspect	გ	z								
SCS	7.5	BL26 top of lap	BL26	suspect	გ	z						-		
SCS	7.5	bkt to web fr tp cx on BL26	BL26	Suspect	ACF.	z								
SCS BCS	9.2	BL28 web lap near bhd	81.28	suspect	Z	z								
SOB	9.2	CVK vert lap near hbd	CVK	suspect	N-CF	z								
9CP	7.6	BL28 cx to 1st stringer	BL28	suspect	₽CF	z						_		
6CP	7.6	HS #3 poss fr 2" in web toe att to LBhd, at of BHd 76	HS3	suspect	yes, 3"	u.		*	*	0.29	0.17	90.	2 no access w/o climbing	o climbing
SCS	7.8	76 HS #3 poss fr 2" in web toe att to LBhd, at of BHd 76	HS3	suspect	yes, 2"	ı.	-	*	×	0,43	0.33	1.00	2 no access w/o climbing	o climbing

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The following persons were members of the Project Technical Committee that represented the Ship Structure Committee to the Contractor as the resident subject matter experts. As such they performed technical review of the initial project proposals to select the contractor, advised the contractor in cognizant matters pertaining to the contract of which the agencies were aware, performed technical review of the work in progress, and edited the final report.

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